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Applied Mechanics Reviews

A Critical Review of the World Literature in Applied Mechanics

L. H. DONNELL, *Editor*

T. VON KÁRMÁN, S. TIMOSHENKO, *Editorial Advisers*

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Abbreviations of units follow the standard of Abbreviations for Scientific and Engineering Terms of the Am. Standards Assoc. Examples: psi (pounds per square inch); cps (cycles per second); mph (miles per hour).

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Applied Mechanics Reviews

A Critical Review of the World Literature in Applied Mechanics

August 1949 Vol. 2, No. 8

Communications and Queries

Concerning Rev. 599, May 1949, "Light gage steel columns in wall-braced panels," by G. G. Green, George Winter, and T. R. Cuykendall.

Editor:

In connection with Rev. **599,** May 1949, of the paper "Light gage steel columns in wall-braced panels," the writer would like to point out that: (1) The critical loads of columns on one to four elastic supports were not derived from Klemperer and Gibbons' differential equations, but by a work-energy method. (2) The expression for external work is indeed incorrect in its application to initially bent columns, even though the strain-energy expression is correct. However, the ten expressions for critical loads are correct for the case of initially straight columns despite this oversight, as can be verified by reducing the analysis to that of straight members by the substitution $y_0 = 0$. These results were checked against Klemperer and Gibbons' for one and two supports, and are extensively verified by test, as noted by the reviewer. (3) The possibility, indicated by the reviewer, that shear distortions of the wallboards may become significant is correct in principle. It so happens, though, that in customary materials of this type the preponderant part of the distortions occurs in the attachments rather than the boards. George Winter, USA

Concerning Rev. 942, June 1948, "The vertical vibration of ships," by C. W. Prohaska.

Editor:

Please correct my review as follows: "An approximate method is presented for calculating the effect of symmetric variations in the moment of inertia which agrees closely with the general method for 74 cases. There is no indication of how well this works for variations not symmetrical about amidships."

J. M. Robertson, USA

Query about Betti's method

Editor:

Can any of your readers tell me if Betti's method for integrating the equations of elasticity [Love's *Elasticity,* 4th ed., p. 232] has been applied to the sphere? R. D. Mindlin, USA

Query about sprays

Editor:

Has anyone developed a fuel or liquid spray in which the sizes of the droplets have actually been measured and the statistical distribution of the sizes is known? A. M. Kuethe, USA

(Answers may be sent to the editor)

New Periodical

Archiwum Mechaniki Stosowanej (Archives of Applied Mechanics), edited by W. Nowacki, Danzig Polytechnic Institute, Danzig, Poland, publishes papers in Polish, English, French and German. The first issue contains papers by Huber, Nowacki, Olszak and Wierzbicki.

Comments invited

. . . . To issue an edition printed on one side of the paper for filing purposes. . . . .

Aurel A. Beles, Politechnica, Bucuresti, Rumania

. . . . Have you considered presenting the material in form suitable for 3 × 5-in. card-index systems? . . . .

Lynn S. Beedle, Lehigh University, Bethlehem, Pa.

. . . . Could not the continuous survey of current literature be supplemented by a systematic survey of already published work? It could begin with a listing of books and general articles. . . . This could be followed by classified lists of more detailed works . . . . Also mention of any book should be accompanied by some information on how to get the book. William Fuller Brown, Jr., Sun Oil Company, Newton Square, Pa.

Theoretical and Experimental Methods

(See also Revs. 971, 977, 1004, 1026)

957. Edited by C. F. Tweney and L. E. C. Hughes, "Chambers's technical dictionary," The Macmillan Co., New York, 1948. Cloth, 5.7 × 8.2 in., 976 pp., no fig., $6.50.

This English technical dictionary will be of use to the research worker when he stumbles over a word in a peripheral region of his field. An illustrative selection of the subjects covered follows: acoustics, ammunition, bookbinding, biology, cinematography, foundry practice, furs, genetics, horology, hosiery, leather, mathematics, painting, printing, psychoanalysis, radar, surgery, telephony, weaving, etc.

Pronunciation is indicated when it is not obvious. No diagrams are used, but structural chemical formulas are shown. Mathematical formulas are occasionally given. Ed.

958. W. Barrois, J. Simon-Suisse, and R. Basile, "Technical introduction to matrix calculus" (in French), *Rech. aéro. Paris,* Nov.-Dec. 1948, no. 6, pp. 3–14.

It is the intention of the authors to develop the methods of matrix calculus in a simple way for the purpose of their practical utilization. Following a short introduction, they present the elements of matrix arithmetic and matrix algebra together with an introduction of the notion of complex numbers. The method is afterward applied to an electric problem.

Maurice Bricas, Greece

959. D. E. Rutherford, "Vector methods," Oliver and Boyd, London, 1948. Cloth, 7.4 × 4.9 in., 135 pp., 16 figs., $2.25.

The book, intended as a textbook for undergraduate students, gives, in remarkably little space, an account of the applications of

vector methods to various topics. After an introductory chapter on vector algebra, the author derives the classical formulas of differential geometry of curves (Frenet's formulas) and surfaces (first and second fundamental form, Gaussian curvature and Meusnier's theorem). In the succeeding chapter, the dynamics of rigid bodies is developed as far as Euler's equation of motion, the conservation of energy and d'Alembert's principle.

In the chapter on the vector operator ∇ the concepts of grad, rot and div are introduced as differential operators and the equivalence with integral definitions is outlined. The expressions in curvilinear coordinates are given, together with the theorems of Stokes, Gauss and Green. These are used in the next chapter on potential theory to derive the expressions for the potential of a volume, surface and dipole distribution. Here, some notions of the theory of electricity are given. The chapter on hydrodynamics gives Euler's equation of motion and Bernoulli's equation with the definition of circulation.

In the chapter on Laplace's equation uniqueness theorems are stated and some simple boundary problems are solved for Laplace's equation and the wave equation (Legendre and Bessel functions). Finally a chapter on four-dimensional vectors is added, with application to electrodynamics and the special theory of relativity. R. Timman, Holland

960. Adalbert Duschek and August Hochrainer, "Fundamentals of tensor calculus in analytic treatment" (in German), Springer-Verlag, Wien, 1948. Paper, 8.2 × 5.2 in., 129 pp., 26 figs., $2.70.

This book is the first of a three-volume treatise on three-dimensional tensor analysis. It is a co-operative effort of a geometer (who previously had published a two-volume treatise on the same subject) and an electrical engineer. The first volume covers the algebra of tensors, redefining the dot-product and cross-product concepts of vector analysis in tensor symbolism. The second volume, judging by the table of contents enclosed, is on the differential geometry of surfaces and on Poisson's and Laplace's equations. The third volume applies these equations to the solution of field problems.

It is regrettable that in offering a new engineering tool the authors restrict themselves to three-dimensional tensor analysis and then even concentrate upon such an overworked territory as the scalar-potential and vector-potential fields. Engineers have already found the electrolytic tank, the d-c board and the punch-card machine as powerful aids in the practical solution of potential field problems, while in their analytical formulation and solution tensor analysis has nothing striking to offer there in competition with vector analysis. The treatise may serve however as an introduction (though a lengthy one) to multidimensional tensor analysis, and thereby to the study of mechanical and electric circuits and machinery.

The basic concepts of tensor analysis find their practical usefulness chiefly in the study of engineering structures where a large number of one-, two- and three-dimensional Euclidean, Riemannian and non-Riemannian spaces are interconnected and interlocked with each other. It is the organization, visualization and manipulation of such complex problems that call for a tensorial method of reasoning, making it worth while for the engineer to learn a host of new concepts and symbols which would be useless to him in simple problems. Gabriel Kron, USA

961. A. F. Timofeev, "Integration" (in Russian), Ogiz, Moscow, 1948. Cloth, 8.9 × 5.75 in., 432 pp., 3 figs.

This is a useful volume, approximating a handbook, devoted to the integration of elementary functions of one independent variable. The chapter headings are as follows:

(1) Fundamental concepts and methods of integration. (2) Integration of algebraic rational functions. (3) Formulas for reduction of integrals involving algebraic polynomials. (4) Integration of irrational algebraic expressions. (5) Integration of trigonometric functions. (6) Trigonometric substitutions for integrals of algebraic expressions. (7) Integration of expressions involving products of algebraic and trigonometric functions. (8) Integration of expressions involving exponential and logarithmic functions. (9) Integration of expressions involving inverse trigonometric functions. I. S. Sokolnikoff, USA

962. L. Bouthillon, "Oscillation and transient phenomena" (in French), Gauthier-Villars, Paris, 1948. Paper, 10.5 × 8.5 in., 47 pp., 33 figs.

The object of this monograph is to give a short outline of operational calculus and its applications to the study of transient oscillations of mechanical and electrical systems. The use of Laplace's and Cauchy's transforms, the inversion theorem, calculation of the transforms, integration of linear differential equations with constant coefficients, and integration of partial differential equations are discussed. Tables of the principal methods of calculation and a certain number of couples of associated functions are given at the end of the monograph.

Enrico Volterra, USA

963. Wilhelm Magnus and Fritz Oberhettinger, "Formulas and theorems for the special functions of mathematical physics," Chelsea Publishing Co., New York, 1947. Cloth, 9.2 × 6.2 in., 172 pp. (transl. from German by John Wermer).

This very useful reference book consists mostly of formulas. No proofs or discussion of methods have been included. Expansions in series of orthogonal functions (save for a few special series developments) and the Lamé functions have been deliberately omitted, and the treatment of the Mathieu functions has been kept to a minimum.

The contents are as follows: The Gamma function, 15 pp. The cylindrical functions (with an appendix on Mathieu functions), 33 pp. Spherical harmonics (with an appendix on the functions of Gegenbauer), 29 pp. Orthogonal polynomials, 8 pp. The confluent hypergeometric function and its special cases, 12 pp. Theta functions, elliptic functions and integrals, 16 pp. Integral transformations and integral inversions (with tables of Fourier and Laplace transforms), 30 pp. Coordinate transformations (with an appendix on linear differential equations of the second order), 18 pp.

A list of abbreviations and function symbols, a bibliography and a general index complete the book. Ed.

964. F. A. Willers (translated by Robert T. Beyer), "Practical analysis," Dover Publications, New York, 1949. Cloth, 9.5 × 6.2 in., 422 pp., 132 figs., $6.

This newly translated book was written in 1928 (the article on the slide rule has been revised, and that on desk machines entirely rewritten by Tracy W. Simpson). It still remains a trustworthy standby aid in simple computational work, of the desk variety. But it must be realized that, in the 20 years since it was first published, computing techniques have made epoch-making progress; it is a comprehensive book no longer. To be that it would have to include first a discussion of IBM machinery, differential and network analyzers, and automatic digital machinery. In the second place, it would have to give an account of the voluminous work on systems of linear numerical equations that has accumulated to the extent of making the book obsolete in this

particular regard. Thirdly, it could not omit a report on numerical methods in partial differential equations (at the least on those of relaxation and characteristics). Finally, it would have to do justice to the recent discovery that the gremlin of the round-off error has been grossly underrated, and tell about the fast-growing and frequently troubled attention that is being given to it now [see Rev. **1552**, Oct. 1948, and von Neumann-Goldstine, *Bull. Amer. Math. Soc.*, Sept. 1947, vol. 53, pp. 1021–1099].

If the user of the book keeps in mind these reservations, he will find in it a useful coverage of the following topics: interpolation, 85 pp.; integration and differentiation, 61 pp.; solution of numerical equations, 94 pp.; differential equations, 62 pp.; and analysis of empirical functions, 75 pp.

The title adopted for this field, invented ad hoc, has never caught on much even in Germany, and does not convey much, if anything, to the English reader. Does the inclusion of graphical methods rule out the title of "Numerical Methods or Procedures?"

A. W. Wundheiler, USA

965. **R. Timman, "The numerical evaluation of the Poisson integral,"** *Nat. LuchtLab. Amsterdam Rap.*, no. F.32, June 6, 1948, 25 pp.

The author computes the function $\tau(\varphi)$, defined by the Poisson integral

$$\tau(\varphi) = -(1/2\pi)\int_0^{2\pi}\sigma(\psi)\cot\tfrac{1}{2}(\varphi-\psi)d\psi,$$

by expanding the function $\sigma(\psi)$ in interpolation polynomials of a type suggested by I. J. Schoenberg [*Quart. appl. Math.*, Apr. 1946, vol. 4: part A, pp. 45–99; part B, pp. 112–141] and integrating approximately. Finally the conjugate function $\tau(\varphi)$ is evaluated by a matrix method developed by the author. The author claims that this method yields more accurate results than those of other papers cited. Tables and graphs facilitating the computation are also included in the report.

John A. Lewis, USA

966. **Enzo Cambi, "Eleven and fifteen-place tables of Bessel functions of the first kind, to all significant orders,"** Dover Publications, Inc., New York, 1948. Cloth, 8.6 × 10.8 in., 154 pp., $3.95.

Table I gives the values of $J_n(x)$ for x ranging from 0 to 10.5 at intervals of 0.01. The order n is extended to values for which $J_{n+5}(x)$ becomes smaller than 0.5×10^{-11}. All values have been computed to 12 places, of which 11 are shown. The last one is crossed or underlined, depending on whether the tabular value is too large or too small, respectively. It is stated that if these marks are taken into account, better accuracy results.

Table II contains the same functions as the previous one but x ranges from 0 to 0.500 at intervals of 0.001 to 15 places and all J_n greater than 10^{-15} are given. All the decimal figures can be regarded as accurate in this table, although an uncertainty of one unit in the last place is possible. Both tables are reproductions of a typewritten manuscript.

The method of computation is described in a brief introduction. Two graphs of upper limits of errors are given for the two tables. An appendix gives the Taylor series for J_n of even order and $x = 2, 3, 4, 5, 6, 7, 8, 9, 10$. A short bibliography closes the book.

Ed.

967. **Computation Lab. Nat. appl. Math. Lab. Nat. Bur. Stand., "Tables of Bessel functions of fractional order, Vol. II,"** Columbia University Press, New York, 1949. Cloth, 10.5 × 8.2 in., 365 pp.

Volume I of this work contained the Bessel functions $J_\nu(x)$ for $\pm\nu = \frac{1}{4}, \frac{1}{3}, \frac{2}{3}$ and $\frac{3}{4}$. The present volume contains the modified Bessel functions $I_\nu(x) = \exp(-\nu\pi i/2)\, J_\nu[\exp(i\pi/2)x]$ for the same orders, and also the functions $\exp(-x)I_\nu(x)$. Ten decimal places or ten significant figures are shown, with the second, and sometimes fourth, differences. There is a table of Everett interpolation coefficients, and one of the coefficients $L_\nu(\mu)$ for interpolation in the ν-direction.

A list of the tables follows. The interval of tabulation is shown in parentheses, as usual. For $I_\nu(x)$,

$\nu = -\frac{3}{4}, -\frac{2}{3}$: $x = 0(.001)1.00(.01)13.00$.
$\nu = -\frac{1}{3}, -\frac{1}{4}$: $x = 0(.001)0.80(.01)13.00$.
$\nu = \frac{1}{4}, \frac{1}{3}$: $x = 0(.001)0.60(.01)25.00$.
$\nu = \frac{2}{3}, \frac{3}{4}$: $x = 0(.001)0.50(.01)25.00$.

For $\exp(-x)I_\nu(x)$, and all the enumerated ν,

$x = 25.0(.1)50(1)500(10)5{,}000(100)10{,}000(200)30{,}000$.

An introduction explains the use of the tables and the interpolation procedures.

Ed.

968. **S. C. Redshaw, "An electrical potential analyser,"** *Proc. Instn. mech. Engrs.*, 1948, vol. 159, no. 38, pp. 55–80.

This paper deals with the construction of an electric potential analyzer which uses the electrical analogy of the finite-difference approximation of Laplace's and Poisson's equation. This instrument consists essentially of a square mesh whose nodal points are interconnected by low resistances, and a base, the corresponding nodes on the mesh and base being connected by high resistances. A current is applied in such a manner that an electric potential is provided, as required, to points on the mesh and the mesh boundary and readings of the potential at each nodal point are recorded. Such an instrument has been constructed and encouraging results have been obtained.

An interesting discussion of the author's paper by men noted in the field of computing devices is included.

Henry J. Barten, USA

969. **I. J. Schoenberg, "Some analytical aspects of the problem of smoothing,"** *Courant Anniv. Vol.*, Interscience Publishers, New York, 1948, pp. 351–370.

This paper is concerned with certain smoothing procedures, their repeated application, and their property not to increase the number of changes in sign ("variation") of the deviations of the sequence being "smoothed."

A frequently used method of smoothing an empirically obtained set of values y_n is by a transformation of the type

$$y_m' = {}_\nu\Sigma_{-\infty}^{+\infty} L_\nu\, y_{m-\nu}. \tag{1}$$

In the first part of the paper, the author restricts Equation (1) so that $(a)\ L_{-\nu} = L_\nu$, $(b)\ \Sigma L_\nu = 1$, and (c) it is "exact" for the degree $2k-1$, that is it transforms every polynomial of degree $2k-1$, but not of degree $2k$, into itself. This is equivalent to assuming that $\varphi(u) = \Sigma L_\nu \exp(iu\nu) = 1 - au^{2k} + \ldots, (a \neq 0)$, this series being convergent for $|Im(u)| < \log \rho$, for some $\rho > 0$. To make the transformation a smoothing one [I. J. Schoenberg, "Contributions to the problem of approximation of equidistant data by analytic functions, part A," *Quart. appl. Math.*, 1946, vol. 4, pp. 45–99], it is assumed (d) that $|\varphi(u)| < 1$ for $0 < u < 2\pi$, which implies that $a > 0$.

If ${}_\nu\Sigma L_\nu^{(n)}\, y_{m-\nu}$ is the n-fold iteration of (1), we have, for $n \to \infty$, up to terms of order of $n^{-1/(2k)}$,

$$L_\nu^{(n)} = \frac{(an)^{-1/(2k)}}{2\pi}\int_{-\infty}^{\infty}\exp(-t^{2k})\cos[t\nu(an)^{-1/(2k)}]dt.$$

In the second part of the paper, which is independent of the first, the author studies the "variation-diminishing" subclass of the transformation (1). The transformation (1), restricted to the case when $\Sigma L_\nu z^\nu$ converges in the neighborhood of $|z| = 1$, and $L_\nu \gg 0$ for all ν, is called variation-diminishing if the number of changes of sign in $\{y_m'\}$ is less than or equal to that of $\{y_m\}$. It is then shown that (1) is variation-diminishing if, and only if, the four-way infinite matrix whose ij element is L_{i-j} has only nonnegative minors.

Finally, a function generating an infinite, and possibly exhaustive, variety of such coefficient sequences is determined, thus establishing a method of constructing variation-diminishing transformations.

The paper closes with a short discussion of the continuous analog of this problem, where the summations are replaced by integrals. Felix Rosenthal, USA

970. Britton Chance, R. I. Hulsizer, E. F. MacNichol, Jr., F. C. Williams, "Electronic time measurements," McGraw-Hill Book Co., New York, 1949. Cloth, 9.2 × 6 in., 538 pp., 383 figs.

As one of the series of 28 volumes in the Radiation Laboratory Series, this book is devoted to the techniques of time measurement upon which radar is based. After an introductory chapter, the second chapter is devoted to a discussion of the various methods of measuring distance and speed with radio techniques. In itself it is a brief but comprehensive review of the various basic schemes and combinations of schemes which have been proposed. A system which is not covered in this chapter would be difficult to conceive.

The remaining chapters are devoted to specific techniques of pulse-time measurement, with many detailed circuit diagrams. Chapters are included on fixed and movable indexes or timing markers, and on manual and automatic time-measurement methods. As a reference work of tried and proven techniques, therefore, the book is invaluable. The contents are not, however, precisely what one would expect from the title. The inclusion, for instance, of chapters on the use of ultrasonic delay devices for the cancellation of recurrent wave forms and on data transmission is unexpected, even though the application of the former technique is one method of improving elapsed-time measurements.

The many references to other volumes in the series gives an annoying impression of lack of completeness in the present work, which is probably not justified. The careful reader will, nevertheless, wish to have conveniently at hand the other volumes in the series. Norman W. Arnold, USA

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 959, 983)

971. "Courant anniversary volume," Interscience Publishers, New York, 1948. 9.7 × 6.5 in., 470 pp., 24 figs., $5.50.

This volume has been edited by K. O. Friedrichs, O. E. Neugebauer, and J. J. Stoker, to commemorate the 60th birthday of Richard Courant, one of the most important men in the field of applied mathematics today. It contains 38 papers of which 10 (by Franck, Hadamard, Lewy, MacDonald, Prager, Hans Reissner, Schoenberg, Taussky, Weinstein, and Zwicky) are reviewed individually. Ed.

972. G. Hamel, H. Cremer, L. Cremer, and K. Federn, "Convention of German mathematicians in Karlsruhe, April 10–12, 1947. III. Dynamics" (in German), *Z. angew. Math. Mech.*, Aug.-Sept. 1947, vol. 25/27, pp. 159–165.

The five notes of this paper deal with: (1) the general heavy top, (2) Routh's and Hurwitz's stability criteria, (3) a new method of stability analysis, (4) plate vibration due to a concentrated periodic force, and (5) recent developments in balancing techniques.

1 (by G. Hamel): Euler's dynamic equations for a rigid body with a fixed point under gravity (general heavy top) lead to three scalar equations of motion in terms of angular momentum, kinetic energy, and spin. The author discusses the special case of constant angular momentum, previously analyzed incorrectly by Schiff and Stäckel.

2 (by H. Cremer): The equivalence of Routh's and Hurwitz's stability criteria is demonstrated. A suitable normalization transforms all elements of the Routh system into subdeterminants of the highest-order Hurwitz determinant. A physical interpretation of the vanishing of the higher Hurwitz determinants follows.

3 (by L. Cremer): A stability criterion, introduced previously for electrical systems by Nyquist and Strecker, is claimed to facilitate numerical computations. It uses the intersections with the real or imaginary axes of a special locus curve of the characteristic equation. The method furnishes the "least-stable" frequency and the degree of stability.

4 (by H. Cremer): The general solution for a vibrating infinite plate with a localized periodic disturbance is given as the sum of two Hankel functions. The forces in the plate are shown to be finite everywhere.

5 (by K. Federn): Calibration of an electromechanical balancing machine can be accomplished by electrical means alone, which dispenses with a perfectly balanced calibration rotor. G. A. Nothmann, USA

973. V. T. Kostitsyn, "On the minimum dimensions of cam mechanisms" (in Russian), *Bull. Acad. Sci. USSR Ser. tech. Sci. (Izv. Akad. Nauk SSSR Ser. tekh. Nauk)*, Oct. 1948, no. 10, pp. 1531–1537.

A cam of minimum radius R and maximum radius $R + H$ actuates a follower, constituted by a rod sliding between two guide rings $2b$ apart, through the intermediary of a roller caster of radius r. The problem is to find the minimum value of the dimensions $2(H + R + b)$ of the casing, for a constant swing H.

This lower bound arises from the condition that self-locking be prevented, or that the angle γ between the bar axis and the cam normal be smaller than a prescribed quantity smaller than the critical value $\tan^{-1} b/f(H + r + b)$ at which the reaction at the center of the caster wheel becomes infinite (f is the coefficient of friction). The product of f and the diameter of the bar is neglected.

A relation between R and b is obtained from the value of the maximum of γ, and is used to find the minimum value of $R + b$ in terms of H, r, f for a certain special prescribed relation between cam and slider motion. A. W. Wundheiler, USA

Gyroscopics, Governors, Servos

(See also Rev. 972)

974. Irmgard Flügge-Lotz, "On the motions of an oscillator under the influence of an on-off servomechanism" (in German), *Z. angew. Math. Mech.*, July 1947, vol. 25/27, pp. 97–113.

The servomechanism considered in the paper is characterized by the equation

$$\ddot{\varphi} + 2\delta\dot{\varphi} + \omega^2\varphi = N\beta.$$

The first case studied is when the input depends on the output and its derivative or when

$$\beta = \pm \beta_0 \operatorname{sgn} (\kappa_1\varphi + \kappa_2\dot{\varphi}).$$

The method of analysis is purely graphical and uses the phase plane with the coordinates φ and $\dot{\varphi}$. Solutions in this plane consist of connected segments of logarithmic spirals. For the second case studied, a dead space for switching is assumed. Both backlash and dead time are considered. As previously, the phase plane is utilized for graphical analysis. For the third case studied, the output velocity is controlled by the input and its derivative or

$$\dot{\beta} = \pm V \operatorname{sgn}(\kappa_1\varphi + \kappa_2\dot{\varphi}).$$

In this case, the motion can be described only in a three-dimensional phase space. Some general conclusions are obtained by studying the "switching points" of the system. General conclusions on the stability of on-off controls are also included. The last section of the paper presents an application to the on-off control of airplanes. Andrew Vazsonyi, USA

975. **Toshirō Terano, "Automatic control of chamber temperature (1st report)"** (in Japanese), *Trans. Soc. mech. Engrs. Japan*, 1948, vol. 14, no. 46, pp. 134–142.

This paper deals with the automatic control of the temperature of a chamber containing a heater when the detector of the temperature, which is connected to the regulator of the heater, is buried in the surrounding wall. The characteristics of this control system, when the temperature outside or inside of the chamber is changed, are studied theoretically. The limit of stability and the critical damping of the control system are obtained. Numerical examples are also presented. Humio Tamaki, Japan

976. **L. Collatz, "Stability of governors with time lag"** (in German), *Z. angew. Math. Mech.*, May 1947, vol. 27, pp. 60–63.

The paper studies the solutions of the equation of an oscillating system subjected, at any time t, both to the conventional forces proportional to distance and speed, and to an external force proportional to the position of the system at a previous time $t - \tau$.

The algebraic quadratic equation in λ, to which the differential equation can be reduced in the usual case, becomes here a transcendental equation including a term $e^{-\lambda\tau}$. This equation depends on τ and three parameters which define the mechanical characteristics of the system.

According to the values of these parameters, it admits 0, 1, 2 or 3 real roots, and an indeterminate number of complex roots. The study of the regions where no root has a positive real part is carried out for $\tau = 1$. This assumption means choosing the time lag τ as the unit of time.

The discussion leads to a graphical plane representation. Graphs are calculated for three given numerical values of the parameter representing the restoring force. They show the location and extent of the stability area in terms of the two remaining parameters. F. C. Haus, Belgium

Vibrations, Balancing

(See also Revs. 972, 974, 976, 993, 1080)

977. **M. Ya. Leonov, "Stability of quasi-harmonic vibration"** (in Russian), *Notes Acad. Sci. USSR (Doklady Akad. Nauk SSSR)*, Feb. 1949, vol. 64, pp. 645–648.

Continuing his investigation of the stability of solutions of the second-order linear differential equation with periodic coefficients, the author shows how the equation $\ddot{x} + a(t)\dot{x} + x = 0$, $a(t)$ periodic with period $L > 0$, ${}_0\int^L a(t)dt = 0$, may be treated using techniques developed in previous papers [*Notes Acad. Sci. USSR (Doklady Akad. Nauk SSSR)*, 1948, vol. 62, nos. 2 and 3; *Appl. Math. Mech. (Prikl. Mat. Mekh.)*, 1946, no. 5-6, 1948, no. 6]. Richard Bellman, USA

978. **Sumiji Fujii, "Time-lag vibration"** (in Japanese), *Rep. Inst. Sci. Technol. Tokyo*, June 1947, vol. 1, pp. 80–83.

The author defines time-lag vibration by the equation

$$\psi(t) = \Phi\{\psi(t - \tau)\}, \tag{1}$$

where $\psi(t)$ expresses the condition of the system at time t, Φ is a given operator, and τ is a constant. If a function ψ_0 exists which satisfies the relation $\psi_0 = \Phi(\psi_0)$, then $\psi(t) = \psi_0$ is a solution of (1). ψ_0 is stable when $|\Phi'(\psi_0)| < 1$, and is unstable when $|\Phi'(\psi_0)| > 1$.

A particular case:

$$\psi(t) = \alpha\psi(t - \tau), \ \alpha > 1, \tag{2}$$

has a solution which is a linear combination of two independent solutions:

$$\psi_n(t) = e^{t/\tau_0} \sin(2n\pi t/\tau_0), \ \psi_n(t) = e^{t/\tau_0} \cos(2n\pi t/\tau_0).$$

The author remarks that this equation is encountered in many practical cases. Lastly, he studies the equation

$$d\theta(t)/dt + \theta(t - \tau) = 0, \tag{3}$$

by putting $\theta = e^{pt}$. It is found that an unstable solution exists in this case of time-lag vibration. Takeo Mogami, Japan

979. **Yoshimaru Yoshimura and Masuji Uemura, "The effect of amplitudes on the lateral vibrations of rods"** (in Japanese), *Rep. Inst. Sci. Technol. Tokyo*, Mar.-Apr. 1948, vol. 2, pp. 57–61.

The exact form of the equation of vibration of a thin rod with an amplitude of arbitrary magnitude is derived. This equation is solved by approximations accurate to the third order of the displacement, and the effect of the amplitude on the period of vibration is discussed. Takeo Mogami, Japan

980. **H. Takeyama, "On the strength and vibration of a rotating bar. I"** (in Japanese), *J. Soc. appl. Mech. Japan*, Sept. 1948, vol. 1, pp. 1–9.

From the fundamental equations of the bending stiffness and lateral vibration of rotating bars, integral equations of Volterra's and of Fredholm's type have been derived for the bending moment and the inclination of the deflection curve. The author calculates by means of these equations the period of vibration for the case when the moment of inertia varies linearly along the bar. Takeo Mogami, Japan

981. **G. Krall, "Dynamics and aerodynamics of wires. III. Nonlinear problems of visible vibrations"** (in Italian), *R. C. Accad. Lincei*, Nov. 1948, ser. 8, vol. 5, sem. 2, pp. 197–203.

The author derives a differential equation for the large vibrations of a transmission line under aerodynamic resistance proportional to the square of the velocity and acted on by a disturbing force which in the approximate solution is taken to be harmonic. This approximate solution is obtained by a least-square procedure. The stability of the oscillations for various profiles of the cross section of the wire is discussed. Edward Saibel, USA

982. **G. Krall, "Dynamics and aerodynamics of wires. IV. Nonlinear problems of acoustic vibrations"** (in Italian), *R. C. Accad. Lincei*, Dec. 1948, ser. 8, vol. 5, sem. 2, pp. 285–288.

The study of the differential equation derived in the preceding note is continued for the case where the wire is subjected to a disturbing force of the type produced by the von Kármán vortex street. The result is a vibration in the acoustic, not visible, range. A numerical example is worked out. Edward Saibel, USA

983. O. Föppl, "Vibrations of a rotating disk considering the tilting of the vibrating masses" (in German), *Mitt. Wöhler Inst. Braunschweig*, 1948, no. 40, pp. 3–38.

The vibration of rotating shafts carrying disks is considered. Limiting cases are studied (1) when the disks are considered as point masses on the shaft, and (2) when the moments of inertia are considered while assuming negligible mass. In general the natural frequencies for the complete system cannot be obtained directly from these component frequencies.

Natural frequencies of the system are considered when the disks precess around the axis of rotation both for the case with an angular velocity of the same sign, and for the case with counter-rotation. For certain systems the former motion produces resonance with the rotation only for frequencies having imaginary magnitudes.

The paper contains considerable repetition, both within itself and of previous work. E. H. Lee, USA

984. Kanae Senda, "On the decay of vibrations of an elastic body due to energy flow into external systems" (in English), *Kyushu Univ. Res. Inst. Elast. Engng. Rep.*, no. 3, 1947, vol. 4, pp. 27–45.

A theoretical analysis is given of torsional oscillation of a system comprising an elastic rod clamped at one end to a semi-infinite mass and at the other end to a rigid rotor. Damping due to the propagation of elastic waves in the large mass is considered. It is concluded that the rate of vibration decay is extremely small and may be neglected in comparison to the decay from other types of energy dissipation. R. N. Arnold, Scotland

985. Yosikazu Sawaragi, "Displacement-type vibrometer utilizing the change of inductance" (in Japanese), *Trans. Soc. mech. Engrs. Japan*, 1947, vol. 13, no. 44, pp. 47–55.

A new vibrometer using a vacuum-tube oscillator is described. The change of inductance of a coil, produced by the motion of a dust core in it, due to the vibration to be examined, is introduced into the tuning circuit in the grid side of the tuned-plate tuned-grid oscillator. This causes a deviation from the tuned state and produces a change of the plate current, which is recorded by the electromagnetic oscillograph. The frequency of oscillation is about 4 megacycles. Humio Tamaki, Japan

Wave Motion, Impact

(See Revs. 986, 988, 1025, 1027, 1029, 1039, 1080)

Elasticity Theory

(See also Rev. 1004)

986. C. G. Pendse, "On the analysis of a small arbitrary disturbance in a homogeneous isotropic elastic solid," *Phil. mag.*, Nov. 1948, vol. 39, pp. 862–867.

The classical theory shows that it is possible to have waves in dilatation θ and rotation (curl) ω simultaneously. (From some textbooks on the subject one can get the impression that the dilatational and the rotational waves are mutually exclusive.) The author shows that it is more precise to say: if the actual motion consists of an "unmixed" wave (either grad $\theta = 0$, or curl $\omega = 0$), the motion is one in which either the rotation or the dilatation does not have the characteristics of a periodic wave (but need not be zero). This may be of use in earthquake theory.

The analysis is completed by a brief sketch of the determination of the motion under arbitrary conditions, using methods of Kirchhoff and Poisson. W. L. Esmeyer, Holland

987. S. Ghosh, "On the torsion and flexure of a beam whose cross-section is a quadrant of a given area" (in English), *Bull. Calcutta math. Soc.*, Sept. 1948, vol. 40, pp. 107–115.

The author extends the method of solving the torsion-flexure problem, which was developed by him in two previous papers [*Bull. Calcutta math. Soc.*, 1947, vol. 39, p. 107; 1948, vol. 40, p. 77], to the case of a beam whose cross section is a quadrant of a geometrical shape symmetric about two perpendicular axes. The solution is given by a function of a complex variable which is here developed in a general form, and is also developed in detail for the special case of a section consisting of the quadrant of a circle.

Z. Bažant, Czechoslovakia

Experimental Stress Analysis

988. R. M. Davies, "A critical study of the Hopkinson pressure bar," *Phil. Trans. roy. Soc. Lond. Ser. A*, no. 821, Jan. 1948, vol. 240, pp. 375–457.

This paper describes improved techniques for measurements of the performance of the Hopkinson pressure bar. The bar, as first conceived, was to determine the magnitude of a rapidly changing pressure applied to one end of the bar. This pressure magnitude was determined by a measurement of the momentum trapped in detachable endpieces at the other end. The new techniques enable smaller pressures to be measured and the relation between pressure and time to be determined.

The development consists of measuring electrically the variation with time of either the longitudinal displacement of the measuring end of the bar or, alternatively, the radial displacement of the cylindrical surface of the bar. The displacements are measured by coupling them to a capacity change in an electric circuit. The pressure bar is the grounded conductor of the capacity unit. The output of the unit is amplified and a record is obtained by photographing a cathode-ray oscilloscope. The gaging circuits, the amplifiers, and the sweep circuits employed are discussed in detail.

The exact equations of longitudinal vibrations of a circular cylinder, due originally to Pochhammer (1876) and Chree (1889), are used to give the order of magnitude of the effects of dispersion on the propagation of a pulse, as distinct from the periodic disturbances. These equations are quite complex but it is possible to deduce from them the phase and group velocities of sinusoidal waves in a bar of finite radius, and to calculate the distribution of the stresses and displacements over the cross section of the bar. The problem as discussed includes a comparison between theory and experiment.

The authors conclude generally that the pressure bar is incapable of accurate measurements of pressures which are subject to changes in times of the order of one microsecond. When the force applied to the pressure bar changes instantaneously from zero to finite values, the pressure deduced from the displacement at the measuring end takes a finite time to rise to an approximately constant value. This time depends on the Poisson's

ratio, radius and length of the bar. The limits of measurement for the bar sizes used in their experiments are discussed in detail.

In an appendix the authors discuss the propagation of a pulse of flexural waves in a cylindrical bar and compare results from the exact (Pochhammer and Chree), Rayleigh, and elementary theories. C. O. Dohrenwend, USA

Rods, Beams, Shafts, Springs, Cables, etc.

(See also Rev. 987)

989. **Helmut Schlitt, "Investigations of a bearing for small angular deflections without any friction and with negligible restoring torque,"** *J. appl. Phys.*, Apr. 1949, vol. 20, pp. 297–301.

This paper discusses the theory and design of frictionless pivot bearings for small angular deflections. Such bearings consist of three metal rods, axially prestressed and crossing at the center of the pivot. These bearings have no friction and furthermore the restoring torque can be made negligibly small for small angles of rotation.

The author derives an expression for the restoring moment, for both axial tension and compression in the metal rods, from the differential equation of their deflection curves, and obtains design equations for the condition of zero restoring moment. He also investigates deviation from zero moment due to inaccurate prestressing and the influence of temperature and angular displacement, and shows how these unfavorable effects can be compensated by using two sets of metal rods, one set prestressed in tension and the other in compression.

Because no bibliography is attached to this paper, the reviewer wishes to draw attention to previous publications on the theory of flexure pivots: F. S. Eastman [*J. aero. Sci.*, Nov. 1937, vol. 5], W. E. Young [*Trans. Amer. Soc. mech. Engrs.*, 1944, p. A–113], and W. H. Wittrick [*Counc. sci. indust. Res. Div. Aero. Rep.*, SM. 108, Jan. 1948]. Nicholas Sag, Australia

Plates, Disks, Shells, Membranes

(See also Revs. 993, 994, 995, 1013)

990. **K. O. Friedrichs, "The edge effect in the bending of plates,"** *Reissner Anniv. Vol.*, J. W. Edwards, Ann Arbor, 1949, pp. 197–210.

This paper gives the theoretician another interesting approach to the problem of evaluating the stresses at and near the boundaries of a flat plate subjected to a lateral loading. While it is illustrated by reference to a relatively simple problem involving the bending of a semicircular plate with the straight edge completely free, it is described as being equally adaptable to any arbitrary distribution of shear, twisting moments and bending moments along the edge of a plate.

In distinction from parallel developments by E. Reissner ["On the theory of bending of elastic plates," *J. Math. Phys.*, 1944, vol. 23, p. 184] and L. Bolle ["Contribution au problème linéaire de flexion d'une plaque élastique," *Bull. Tech. Suisse Romande*, 1947, pp. 281–285 and 293–298] which include the edge effects with the general solution, the present method involves their separate evaluation to any desired degree of accuracy, the results being superimposed upon those obtained by Kirchhoff's theory which is valid throughout the interior of the plate. This procedure offers the advantage that the magnitude and extent of the edge effects are readily recognized; they are found to be highly localized and, for all practical purposes, vanish well within one plate thickness from the edge. A. R. C. Markl, USA

Buckling Problems

991. **W. Wierzbicki, "Numerical methods in buckling problems"** (in French), *Arch. Mech. stos.*, 1949, vol. 1, pp. 23–66.

Numerical computation of critical loads in stability problems is based either on iterations or on finite differences. The first method was initiated by L. Vianello, the second one (on the occasion of his work on elastic hinges) was applied for the first time by H. Hencky. The paper develops both methods, showing that they are capable of any accuracy, and applies them to stability problems of beams, plates and arches.

After a comparison with results obtainable with exact procedures, he turns to the following cases: (1) An elastically clamped beam under the action of its own weight and a load applied to one of its ends. (2) A square plate supported along two opposite edges and uniformly loaded along the two other edges, which are clamped. (3) Uniformly loaded parabolic arches with none or with two hinges. In this last case the author assumes that the axis of the arch buckles antisymmetrically. The hingeless arch is treated as a limiting case of an elastically clamped arch. The author's numerical results for arches of different rises approximate those obtained experimentally by Gaber in 1943.
J. Mutermilch, Poland

992. **C. B. Biezeno and J. J. Koch, "On the buckling of a girder, elastically supported and elastically clamped in a number of equidistant points"** (in English), *Appl. sci. Res. Sec. A*, 1949, vol. 1, no. 4, pp. 249–257.

A formal solution is given for the deflection of a column sustaining a compressive load and having n equal spans, when the intermediate supports are transversely elastic and also provide elastic rotational clamping, and the end supports are transversely rigid but provide elastic rotational clamping. Critical values of the load are shown to be given by any root of any of $(n + 1)$ equations.

The results of considerable computational work are summarized in tabular form, from which the critical values of the load can be determined for values of n from 1 to 9 and (with interpolation) for ranges of values of the transverse and clamping stiffnesses of the supports. D. N. De G. Allen, England

993. **Bernard Budiansky and Pai C. Hu, "The Lagrangian multiplier method of finding upper and lower limits to critical stresses of clamped plates,"** *Nat. adv. Comm. Aero. Rep.*, no. 848, 1946 (issued in 1949), pp. 1–9.

The fundamental principles of the Lagrangian multiplier method are presented and applied to the problem of finding upper and lower limits to the true compressive buckling stress of a clamped rectangular plate. The possibilities of applying the same method to other stability and vibration problems are outlined. Enrico Volterra, USA

994. **H. L. Cox, "The buckling of a flat rectangular plate under axial compression and its behavior after buckling,"** *Rep. Memo. aero. Res. Counc. Lond.*, no. 2041, May 1945 (issued in 1948), 28 pp.; no. 2175, Oct. 1945 (issued in 1948), 8 pp.

The first part of this paper deals with the general theory of plate buckling and the second part with the conditions for permanent buckles.

In the first part the author considers the problem of flat rectangular plate buckling using the strain-energy method. The buckling stresses, the critical stresses, and the behavior after bending with regard to the edge conditions are analyzed and

critically discussed; the importance of edge restraint to rotations and translations is emphasized. The influence of various factors such as edge deformation, ratio of dimensions and thickness, initial deformation and elastic failure of the material is considered with reference to practical problems.

The second part deals with the conditions of permanent buckling, and different criteria of elastic failure are considered. On account of the mathematical complications only general formulas for stresses are given; detailed results are given only for free edges. Recommendations follow for the practical use of the formulas in the design of panels for airplanes, and the problem of the danger of the "proof load" is discussed.

Although this paper contains no new theoretical results it deserves special atten ion because of the systematic presentation and the interesting applications to practical problems. A general comment by the author on the whole problem of instability of plates and shells with regard to elastic failure of the material would be a valuable contribution. Aurel A. Beles, Rumania

995. A. van der Neut, "Experimental investigation of the post-buckling behaviour of flat plates loaded in shear and compression" (in English), *Nat. LuchtLab. Amsterdam Rap.*, no. S.341, Oct. 8, 1948, 32 pp.

This paper presents the results of experiments on thin rectangular plates under shear load and compression load parallel to the short edges. The main purpose of the tests was to determine the validity of Koiter's theory of the postbuckling behavior of flat plates. The primary load parameters were taken as γ_{cr}/γ (or γ_0/γ) and ϵ_2/γ, where γ is the measured shear angle of the plate, $\gamma_{cr}(\epsilon_1, \epsilon_2)$ is the calculated shear strain at which buckling occurs, $\gamma_0(\epsilon_1, \epsilon_2)$ is the calculated shear strain at which buckling in diagonal rather than compressive waves occurs, and ϵ_1, ϵ_2 are the compressive strains in the longitudinal and lateral directions. All plates had ratios of sides $a/b = 3.16$, with the long sides supported and short sides clamped. Thickness ratios b/t were 118, 167, and 357.

Results are expressed in terms of seven factors which represent the influence of the buckled form on the membrane and bending stresses. The four coefficients used to show the effect of the incomplete tension field on the membrane stresses were determined from measurements of slopes over the plate surface. The bending and torsional strains were calculated from measurements of the amplitude, wave length, and direction of the waves, assuming the buckled wave form to be given by a simple formula.

The results are plotted as functions of γ_{cr}/γ or γ_0/γ only. It was found impossible to distinguish effects of ϵ_2 and ϵ_1, partly because these were difficult to control closely, and partly because of the large scatter of results. For comparison with the experimental results the author plots curves calculated from simplified formulas of Koiter's theory. With some important exceptions, the measured points fall generally within the ranges predicted by theory for the known ranges of ϵ_1 and ϵ_2. P. S. Symonds, USA

996. W. van der Eb, "Some special cases of buckling" (in Dutch with English summary), *Ingenieur 's-Gravenhage*, Mar. 25, 1949, vol. 61, pp. O. 11–18.

This paper is intended for practical application of the author's previous work and the mathematical derivations therefore appear in condensed form. For more detailed information reference is made to Rapport no. 21, Nijverheidsorg.T.N.O., Commissie inzake Onderzoek Constructies, Werkgroep Staalconstructies, May 1948.

The first problem dealt with is that of a column consisting of two beams connected at equidistant intervals by battens; the stiffness of the battens is accounted for by assuming a portion of the column at the battens to be infinitely rigid. The second problem is that of the column on equidistant and equal elastic supports; this is discussed in connection with the stability of the compression chord of a truss, which is secured against sidewise buckling only by the stiffness of the laterals at panel points. The novelty is that the column is not only elastically supported at intermediate points but also at the ends. The starting point of the mathematical derivations is the equation of flexure for an arbitrary bay of column or chord.

Extensive tables are provided to aid in numerical calculations, of which one example each of column and chord are given.

F. Hymans, USA

Joints and Joining Methods

(See also Rev. 1000)

997. C. Mylonas, "Photoelastic stress-determination in glued joints," *Aero. Res. tech. Notes*, no. 72, Dec. 1948, 9 pp; no. 73, Jan. 1949, 10 pp.

The author simulated glued lap joints with photoelastic models, and found for the case of a semicircular shape of the glue boundary that the stress concentration is 50 per cent larger than would be expected according to some theoretical calculations. The complete report of the test was presented at the Seventh International Congress of Applied Mechanics.

A. J. Durelli, USA

Structures

(See also Revs. 991, 996, 1079)

998. Constantin N. Avram, "Generalization of the Cross method" (in French), *Bull. sci. Éc. polyt. Timisoara*, 1948, vol 13, no. 2, pp. 193–216.

After the first publications of Hardy Cross, many other workers have further developed the method and made it suitable for intricate problems. The author gives a general description of the principles of the method, taking full account of the work of other authors. This first article, part of a series, deals only with frameworks with fixed joints. It forms a clearly written compilation.

R. G. Boiten, Holland

999. F. R. Steinbacher and Hsu Lo, "Determination of bending moments in pressure-loaded rings of arbitrary shape when deflections are considered," *Nat. adv. Comm. Aero. tech. Note*, no. 1692, Sept. 1948, 127 pp.

Noncircular rings loaded by uniform internal pressure tend to become circular. Such deflections reduce the bending moments in the ring. These effects are accounted for by expressing the bending moment in terms of the final (deflected) dimensions and by expressing these dimensions in terms of the final bending moments. The resulting integrodifferential equation is solved by means of Fourier series and the results are plotted for two basic ring shapes, one elliptical and one composed of two semicircles joined by straight lines. The method was checked experimentally and excellent agreement was obtained.

F. R. Shanley, USA

1000. Basil Sourochnikoff, "Wind stresses in semi-rigid connections of steel framework," *Proc. Amer. Soc. civ. Engrs.*, Feb. 1949, vol. 75, pp. 235–246.

The object of this paper is to develop a method to permit the

checking of semirigid connections in structures for overstress under combined gravity and wind loads, without requiring the exact determination of stresses due to gravity load. The formulas deduced make use of the moment versus angular deflection diagram of semirigid connections, giving due consideration to the effects produced not only by the application of the side loads but also by their subsequent removal and reversal. Upon working out a numerical example of a bent, subject to a uniformly distributed vertical load and a side load, the author discusses the general case of semirigid frameworks. F. Hymans, USA

1001. **Paul Kuhn and James P. Peterson, "Shear lag in axially loaded panels,"** *Nat. adv. Comm. Aero. tech. Note*, no. 1728, Oct. 1948, 24 pp.

For such engineering purposes as determining the maximum stresses due to shear lag in sheet-stringer panels, it is convenient to replace the entire group of interior stringers by a single substitute stringer suitably located to provide an effect comparable to that of the integrated group. This paper presents an empirical formula for locating the substitute stringer in a panel of semi-infinite length for proper diffusion of load from an axially loaded edge member to the other stringers. The theory of shear lag for the cases of transverse members of infinite stiffness and of finite stiffness is reviewed and is used, together with experimental data, as a basis for the empirical relation. John E. Goldberg, USA

1002. **Jean Ferrandon, "A method to increase rigidity in suspended structures"** (in French), Gauthier-Villars, Paris, 1947. Paper, 10.3 × 8.4 in., 55 pp., 16 figs.

It is proposed to diminish the deflections of small suspension bridges by prestressed cables in the plane of the floor. Deflections found by tests were in good agreement with the theory presented.
P. P. Bijlaard, USA

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 1009, 1024)

1003. **William Prager, "Recent developments in the mathematical theory of plasticity,"** *J. appl. Phys.*, Mar. 1949, vol. 20, pp. 235–241.

This paper is a general survey of recent developments in the mathematical theory of plasticity, and was presented by the author to the Seventh International Congress of Applied Mechanics in London, September 1948. The first part is devoted to the formulation of basic concepts on plasticity and deals with much of the author's important contributions to plasticity theory. The condition of continuity, the condition of uniqueness, the conditions of irreversibility and consistency, and the incremental versus finite stress-strain laws are discussed.

The second part of the paper illustrates various problems of plastic equilibrium. Structural stability in the plastic range is reviewed and the difficulties arising in the formulation of stability problems for nonconservative systems are pointed out. Statically determinate problems in the St. Venant-von Mises theory of plasticity are discussed with special reference to discontinuous solutions. The last part of the paper is devoted to the "shake-down" problem in an elastoplastic structure which is subjected to loads which vary in a random manner between given extreme values. Enrico Volterra, USA

1004. **R. Moufang, "Finite deformations with conservation of volume"** (in German), *Z. angew. Math. Mech.*, Nov.-Dec. 1947, vol. 25/27, pp. 209–214.

The author desires to generalize to finite strains the resolution of the deformation into a pure dilatation and a pure shape distortion, which is usual with infinitesimal deformations; that is, a strain deviator for finite strains is wanted.

If x^i and x'^i are, respectively, the original and the instantaneous coordinates of a particle, and if $ds'^2 - ds^2 = 2\Sigma S_{ik}dx'^i dx'^k$, S_{ik} is the deformation tensor, and the familiar basic invariants are given by $J_1 = \Sigma S_i{}^i$, $J_2 = \frac{1}{2}\Sigma(S_1{}^i S_2{}^k - S_2{}^i S_1{}^k)$, $J_3 = \det(S_i{}^k)$. The metric tensor g_{ik}, defined by $ds'^2 = \Sigma g_{ik}dx'^i dx'^k$, is used to raise indexes. The known formula for the volume change,

$$(dV/dV')^2 = 1 - 2J_1 + 4J_2 - 8J_3$$

is very neatly derived.

Now the deviator A_{ik} is sought in the form $S_{ik} - \frac{1}{2}\varphi g_{ik}$, and the following equation for $1 + \varphi = \lambda$ is found:

$$\lambda^3 - 2J_1\lambda^2 + 4J_2\lambda - 8J_3 = 1.$$

This equation may have three real roots, hence the deviator is not necessarily unique. The author gives the approximation

$$\lambda = \frac{2}{3}J_1 + \frac{4}{9}J_1 - \frac{4}{3}J_2 + \frac{16}{81}J_1{}^3 - \frac{8}{9}J_1J_2 + \frac{8}{3}J_3$$

by expanding the Cardano formula. Successive approximations can be applied. The foregoing deviator is substituted into a stress-strain law proposed by R. Schmidt, and the special form obtained is given.

This reviewer notes that an additive resolution of the deformation tensor for finite displacements is not paralleled by a corresponding resolution of the displacements.
A. W. Wundheiler, USA

1005. **J. L. M. Morrison, "The criterion of 'yield' of gun steels,"** *Proc. Instn. mech. Engrs.*, 1948, vol. 159, no. 39, pp. 81–94.

This report describes tests (tension, compression, torsion of solid and hollow cylinders, bending, internal pressure) made on a standard British nickel-chrome-molybdenum gun steel, as well as tension and torsion tests on seven different wartime alternative gun steels. The standard material in bar form and tempered showed yielding (drop of stress at the beginning of plasticity) in each type of loading. This material in forged form and the alternative steels showed no yielding.

It is concluded from comparison of yielding and flow conditions that the criterion for yielding (the initial drop in load) is the reaching of a critical maximum shear stress, while continuing plastic flow occurs in accordance with the von Mises-Hencky criterion (Nádái's octahedral stress). For the materials which showed no drop in load, plastic flow begins and continues according to the von Mises-Hencky conditions. Merit P. White, USA

1006. **W. M. Shepherd, "Plastic stress-strain relations,"** *Proc. Instn. mech. Engrs.*, 1948, vol. 159, no. 39, pp. 95–114.

This report discusses stress-strain relations in situations where elastic and plastic strains are of the same order of magnitude. The method is based on the idea that, if a material is in the plastic state under a certain state of stress, a small change in the stresses will cause additional plastic and elastic straining under some conditions, and only elastic straining under others. In the former event, the increments of elastic strain are given by Hooke's law, while the plastic increments are expressible in terms of increments of a "plastic-flow function" and functions of the principal stresses. The plastic-flow function is assumed to be dependent only on the state of stress and is assumed here first to be a function of the von

Mises equivalent stress (Nadai's octahedral stress), secondly to be a function of the maximum shear stress. In each case its form can be found from a measured stress-strain curve of any kind.

The behavior of thin-walled tubes stressed longitudinally beyond the elastic limit and then subjected to an increasing torque is considered, and the resulting strains are found.

Merit P. White, USA

1007. Walter R. Hibbard, Jr., "Plastic deformation of large grained copper specimens," *Metals Technol.*, Sept. 1948, vol. 15, T. P. no. 2469, 21 pp.

As the author notes, the increased strength of polycrystalline metals compared with that of its individual crystals has generally been associated with complex stress distributions at the grain boundaries resulting from atomic irregularity between grains, and with the necessity for adjacent crystals to deform compatibly regardless of the single-crystal crystallographic strain mechanism. The purpose of this investigation was to attempt to clarify the gap between single crystals and crystalline aggregates by an analysis of the effects of deformational stresses.

The author describes numerous tests on copper, and shows that the introduction of even a single grain-boundary into a metal crystal specimen, in such a manner as to produce areas deforming differently under stress, causes marked deviations from the theoretical single-crystal behavior described by Taylor and Elam.

He concludes that the inhomogenous deformation is apparent in two ways: (1) Slip interference usually occurring in the early stages of plastic deformation involves no measurable shear at the grain boundary, adjacent to an area of shear variation from no shear to a maximum amount of shear on that slip system which is predicted from single-crystal considerations. (2) When the resolved shear stress becomes sufficiently large to deform the boundary or to cause the operation of slip systems adjacent to it, the complexities of stress and strain are such that no simple analysis of the resulting plastic deformation is possible from existing information. Probably two or more slip systems act to produce more shear at the boundary than in the interior of the grain; this is called "forced slip." This phenomenon is probably by far the most important factor in the deformation of polycrystals.

Henri M. Schnadt, Luxemburg

1008. A. H. Cottrell, "Effect of solute atoms on the behaviour of dislocations," *Rep. Conf. Strength Solids Univ. Bristol*, July 1947 (publ. in 1948), Physical Society, London, pp. 30–38.

In this paper the author deals with the consequences of the fact that solute atoms tend to move in the stress field of an elastic dislocation, large atoms (compared to the size of the solvent atoms) moving toward the expansion side of the dislocation, and small atoms moving toward the compression side. First the author estimates the force on a solute atom exerted by a stationary dislocation, taking this as the gradient of an "interaction energy" defined as the change in the strain-energy field of a dislocation caused by the expansion of a solvent atom to the size of a solute atom. The author then considers semiquantitatively the conditions under which an "atmosphere" of solute atoms can form about a dislocation. In particular a large enough supply of solute atoms (per dislocation) must be present, and at any given temperature the dislocation must not be moving with too high a velocity to prevent a solute atom from catching up with it.

When such atmospheres can form they may have important relations to observed creep and yield-point phenomena. A slowly moving dislocation will have a dragging force exerted on it by an atmosphere of solute atoms because of the asymmetry of the atmosphere in front of and behind the dislocation. The author's numerical estimates indicate that the microcreep rate of tin should be governed by this mechanism. The yield points of mild steels and commercially pure iron may likewise be explained as occurring when the applied load is raised to the point sufficient to pull the dislocations out of their atmospheres. The author suggests that the strain-aging phenomenon of steel supports this picture of the yield point; F. R. N. Nabarro [*Rep. Conf. Strength Solids Univ. Bristol*, pp. 38–45] has since corroborated and extended this theory by combining it with the usual theory of age hardening.

P. S. Symonds, USA

Failure, Mechanics of Solid State

(See also Revs. 1007, 1019)

1009. Franz Lihl, "Crystallographic phenomena at the yield point of steel and their importance for fatigue resistance" (in German), *Metall*, Dec. 1948, no. 23/24, pp. 391–396; Feb. 1949, no. 3/4, pp. 49–51.

The change of X-ray back-reflection diagram taken with cobalt radiation on conical films has been examined during static bending tests on specimens of mild steel. In the elastic range up to 22 kg per sq mm the lattice parameter changes in proportion to the bending; this change decreases more and more as the stress is increased, and finally ceases and goes in the opposite direction. The average peripheral breadth of the reflection spots on the (310)-ring decreases after a linear increase a little and then increases rapidly again. The number of reflection spots on the ring remains nearly constant in the elastic range; then it increases markedly and finally decreases rapidly after having reached a maximum. The result of this is that beyond a certain deformation a subdivision of the reflection spots takes place at first before the extensive broadening, which is characteristic of plastic deformation, begins.

These observations are considered to confirm the opinion of A. Eichinger [*Arch. Eisenhüttenw.*, 1944-1945, vol. 18, pp. 73–90] that the strongly marked yield point of mild steel is due to the breakdown of a special intercrystalline mosaic-block structure. The application of these considerations to alternating loading leads to an interpretation of the fatigue limit as a result of two interacting effects, namely the blocking of the mosaic-block limits and the strain hardening of the mosaic blocks.

Hermann Möller, Germany

Design Factors, Meaning of Material Tests

(See Rev. 1005)

Material Test Techniques

(See also Revs. 988, 1005, 1071)

1010. Lawrence K. Hyde, "Methods and equipment for controlling speed of testing," *Proc. Amer. Soc. Test. Mat.*, 1948, vol. 48, pp. 1191–1200.

A device for controlling the rate of straining of the specimen is described, which enables the testing-machine operator to obtain a predetermined uniform rate of straining throughout the elastic and plastic range of the test specimen. The author also describes a simple time-interval indicator which records on an autographic stress-strain record the elapsed time in increments of one tenth of a minute.

K. W. Johansen, Denmark

1011. **R. Pohlman, "On the possibilities of nondestructive material testing by means of ultrasonic projection"** (in German), *Schweiz. Bauztg.*, Feb. 5, 1949, vol. 67, pp. 85–90.

In simple exploration with ultrasonic waves, which are sent into one side of the specimen to be tested and detected by a receiver on the other side, the sensitivity in perception of defects decreases considerably when the disturbance is far from the receiver. This disadvantage can be removed by collecting the rays with an acoustic lens and projecting them on a screen where they register as visible signals. Chloroform or carbon tetrachloride enclosed between thin curved foils have proved to be good lens materials, if the surrounding medium consists of water or other fluid of similar wave resistance. The screen uses the well-known directional effect which ultrasonic waves exert on fine metal leaves suspended in a fluid.

The apparatus used for these tests involves two supports. The rear one carries the high-frequency generator actuating the acoustic transmitter (quartz crystal), while the front one has the screen mounted on it. The position of the rear one is adjustable, so that specimens from 0 to 500 mm thickness can be tested. The transmitter and screen are forced against the specimen by compressed air, and coupled to it by mercury, using exchangeable coupling chambers with diameters of 20 to 100 mm. For large specimens, a special telelens is used by which defects at depths up to 30 to 250 mm can be observed on the screen.

The apparatus makes it possible to determine defects of the order of magnitude of 1 sq mm area and 10^{-4} mm thickness in small specimens, as well as to explore objects of considerable size in which the penetration of large thicknesses is more important than good resolution. As an example of applications, the author discusses tests on light-metal spot welds and the investigation of defects in a locomotive firebox. E. Siebel, Germany

Mechanical Properties of Specific Materials

(See also Revs. 1005, 1007, 1009)

1012. **A. E. Johnson, "The plastic, creep and relaxation properties of metals,"** *Aircr. Engng.*, Jan. 1949, vol. 21, pp. 2–8, 13.

The author reports the first results of an investigation of the plastic, creep and relaxation properties of metals under complex-stress systems at elevated temperatures. He presents data on the criterion of elastic failure and the complex-stress creep properties for a low-carbon steel (C 0.17, Si 0.20, Mn 0.64 per cent) and for an aluminum alloy, Hidiminium RR 59. Special attention was given to assure isotropy in the test materials.

The criterion for elastic failure was investigated by determining limits of proportionality, yield points and a proof stress corresponding to 10^{-5} plastic strain, in combined tension and torsion tests at temperatures from 20 to 550 C for the low-carbon steel and 20 to 200 C for the aluminum alloy. It was found that the low-carbon steel failed elastically when the ratio of torsion and tension stresses exceeded a value corresponding to the theory of constant shear-strain energy, but the aluminum alloy failed either when the distortional shear-strain energy or when the total strain energy exceeded a certain value. The creep properties under complex-stress systems (tension and torsion on a tubular specimen) were determined at 350 C for the low-carbon steel and at 150 and 200 C for the aluminum alloy.

In a very thorough discussion of the results the author draws the following conclusions from the tests: (1) The creep strain appears to follow the von Mises-Hencky shear-strain-energy criterion of yielding. (2) Creep rate-stress relations of the St. Venant-von Mises equation type, as advanced by Odqvist, and Marin and Soderberg, appear to represent the creep of normal materials over ranges of moderate stresses where isotropy is preserved.

The test results corresponded to the following creep rate-stress relations: For the low-carbon steel at 350 C,

$$C_1 = \{A\Sigma(\sigma_1 - \sigma_2)^2 + A_1[\Sigma(\sigma_1 - \sigma_2)^2]^m\}[(\sigma_1 - \sigma_2) - (\sigma_3 - \sigma_1)].$$

For the aluminum alloy at 150 C,

$$C_1 = \{A + A_1[\Sigma(\sigma_1 - \sigma_2)^2]^{m_1} + A_2[\Sigma(\sigma_1 - \sigma_2)^2]^{m_2}\}[(\sigma_1 - \sigma_2) - (\sigma_3 - \sigma_1)].$$

For the aluminum alloy at 200 C,

$$C_1 = \{A[\Sigma(\sigma_1 - \sigma_2)^2]^{m_1} + A_1[\Sigma(\sigma_1 - \sigma_2)^2]^{m_2}\}[\sigma_1 - \sigma_2) - (\sigma_3 - \sigma_1)].$$

Here C_1 is the creep rate in the direction of the largest principal stress, and σ_1, σ_2, σ_3 are the algebraically largest, smallest and intermediate principal stresses respectively.

Sven Edling, Sweden

1013. **Fred Werren, "Fatigue of sandwich constructions for aircraft,"** *For. Prod. Lab. Rep.*, no. 1559-A, Dec. 1947, 6 pp.; no. 1559-B, Apr. 1948, 6 pp.; no. 1559-C, Aug. 1948, 8 pp.; no. 1559-D, Sept. 1948, 7 pp.

Tests wherein materials of sandwich construction have been subjected to repeated shearing loading are reported. Load was applied at a frequency of 900 cpm, the maximum load of the cycle being 10 times the minimum. Static tests on control specimens were also made.

The four reports describe tests on the following five constructions: paper-honeycomb, end-grain-balsa and fiberglas-honeycomb cores between aluminum faces, and end-grain-balsa and fiberglas-honeycomb cores between fiberglas-laminate faces.

S-N curves up to 3×10^7 cycles are presented in each case. Failing load is presented as a percentage of the average strength of the corresponding control test specimen. Curves for end-grain-balsa and paper-honeycomb cores show a concavity downward, while that for fiberglas honeycomb is practically a straight line up to about 10^7 cycles. In the latter case there was practically no difference between the performance with aluminum or fiberglas-laminate faces. When end-grain balsa was used as a core better fatigue performance was obtained with fiberglas-laminate faces than with aluminum faces.

None of the tests provides any firm basis to presuppose the existence of an endurance limit for this class of constructions.

F. T. Barwell, England

1014. **R. S. Jensen, "Fatigue tests of manganese steel,"** *Bull. Amer. Rly. engng. Ass.*, Feb. 1949, vol. 50, pp. 579–588.

This paper contains the results of reversed bending tests at 800 cps on flat specimens with a T-shaped test cross section, made from "Hadfield manganese steel." The test conditions were chosen to correspond to the working conditions for a rail-crossing part, and they included the influence of the surface treatment (cast, ground, shot-peened) and the influence of corrosion on an unprotected and on a coated surface of the specimen (protective paint coating). In all tests the maximum tensile stress had a ratio of 0.5 to the maximum compressive stress. The tests without corrosion and the corrosion tests on coated specimens were carried out to ten million cycles. The beneficial effect of shot peening in increasing the fatigue life of the specimens without corrosion and of the coated specimens under acid corrosion is particularly remarkable. In the corrosion fatigue tests with unprotected specimens,

specimens with all three surface treatments withstood about the same stress for one million cycles. Max Hempel, Germany

1015. I. Cornet, "Factors affecting the tensile notch sensitivity of magnesium alloy extrusions," *Metals Technol.*, Aug. 1948, vol. 15, T. P. no. 2419, 23 pp.

The tensile notch sensitivities of extrusions of several magnesium alloys and aluminum alloy 24S-T, and cast bars of magnesium alloy C and aluminum alloy 122-T2 were studied in axial and nonaxial tension in the "as-received" condition. Magnesium O-alloy extrusions were subjected to experimental heat-treatments, and the resulting hardness, tensile strength, microstructure and notch sensitivity observed. The notches were of the 60-deg V type with a root radius of approximately 0.0002 in. The notch sensitivity is expressed as 100 times the ratio of the notched ultimate tensile strength to the unnotched ultimate tensile strength.

The most significant conclusions reached are: (1) Extrusions of magnesium alloys J, O and X and aluminum alloy 24S-T show notch strengths higher than their unnotched ultimate strengths. Extruded magnesium M alloy shows little notch effect, while the cast magnesium and aluminum materials are reduced in strength by notching. (2) The notch sensitivity of the as-received materials does not correlate with any conventional tensile-test parameter. (3) For the bar designs studied, a minimum notch ductility of about 2 per cent reduction in area at the notch is required for notch strengthening in axial tension; where the reduction in area at the notch was less than approximately 2 per cent, the notched strength fell below the unnotched strength of the material. (4) Magnesium O-alloy extrusions, when solution heat-treated, quenched and aged, exhibit a marked increase in notch sensitivity with aging time. Harry Schwartzbart, USA

1016. Charles A. Hoffman, G. Mervin Ault, and James J. Gangler, "Initial investigation of carbide-type ceramal of 80-percent titanium carbide plus 20-percent cobalt for use as gas-turbine-blade material," *Nat. adv. Comm. Aero. tech. Note*, no. 1836, Mar. 1949, 49 pp.

This report describes an investigation of the physical problems arising in the use of the certain ceramals for gas-turbine blades. X-ray diffraction studies were made of ceramal turbine blades befor and after operation; also, for comparison purposes, zircon and titanium carbide ceramics and an alloy were investigated for thermal-shock characteristics and turbine-blade performance.

It is concluded that: (*a*) The 80 per cent titanium carbide plus 20 per cent cobalt carbide-type ceramal shows promise for gas-turbine-blade application at relatively high temperatures for short times. (*b*) Blades of carbide-type ceramals having high thermal conductivities cause the turbine-disk rim to run hotter than do metal blades. (*c*) During operation, a tenacious scale formed on the ceramal blades, tending to preserve their aerodynamic shape.
Bennett H. Edelman, USA

1017. J. M. Hodge, J. L. Giove, and R. G. Storm, "The hardenability effect of molybdenum," *J. Metals*, Mar. 1949, vol. 1, pp. 218–227.

The paper shows that additions of fractional percentages of molybdenum retard the bainite transformation, and therefore increase the hardenability in a nickel steel more than in a comparable chromium steel. J. C. Fisher, USA

1018. Duncan McConnell, R. C. Mielenz, W. Y. Holland, and K. T. Greene, "Cement-aggregate reaction in concrete," *J. Amer. Concr. Inst.*, Oct. 1947, vol. 19, pp. 93–128.

One source of concrete deterioration which has become a serious problem in some regions is the reaction of certain aggregates with alkalis which are released during the hydration of high-alkali Portland cements. This paper reports an investigation of the causes, details and means of identification of the phenomenon, characteristics of cements and aggregates which contribute to it, and controls and prevention. Petrographic examination of concrete for the presence of exudations or deposits of siliceous gels and the occurrence on aggregate grains of reaction rims formed after mixing the concrete are the methods for identifying the cement-aggregate reaction; detailed descriptions are given. Mortar bars made from a number of aggregates were studied for linear expansion up to two years. The amount of expansion depends upon the amount, size and reactivity of the aggregate, but no general quantitative explanation of each factor can be made.

Physicochemical investigations of pH of aggregate slurries, reaction of aggregate components with alkaline solutions and determination of the amount of silica released from aggregates into aqueous solution do not yield conclusive results. Tests for osmotic pressure developed in water glass sealed in concrete indicate that the concrete serves as a semipermeable membrane, permitting water to enter and increase the pressure of the water glass to values of the order of 500 psi. Such pressures are sufficient to produce tensile fracture, and offer an explanation of the cause of the cracking deterioration. Henry A. Lepper, Jr., USA

1019. C. D. Weir, "Recent research on caustic cracking in boilers," *Trans. Instn. Engrs. Shipb. Scot.*, Jan. 1949, vol. 92, pp. 165–192.

This is a review of the present status of the problem of caustic cracking. The opinions of leading investigators are not always in harmony and often appear to be based on very little experimental evidence.

The first part of the paper describes caustic cracks and embrittled plates and shows how the concentration of a salt in boiler water may be increased in the vicinity of a crack or small opening. The factors which are thought to stimulate or inhibit caustic cracking are discussed, including the polarity of an electric potential at the wall surface, the effect of several chemicals on the embrittling action of sodium hydroxide, the effect of the stress, and the quality of the steel.

Several theories of caustic cracking and some evaluations of test data in their light are presented. The author then discusses the idea that embrittlement is caused by hydrogen occluded by the metal, the benefits of cathodic polarization, and the theory that an unfavorable polarization may be set up by local corrosion and that this electrolytic action results in atoms being removed from the grain boundaries, thus favoring intergranular fracture.
Evan A. Davis, USA

Hydraulics; Cavitation; Transport

(See also Revs. 1025, 1028, 1030, 1044, 1079)

1020. Auguste Folquier, "Analytic application of Kirchhoff's laws" (in French), *Rev. gén. Hyd.*, 1948, vol. 40: Mar.-Apr., no. 44, pp. 71–78; May-June, no. 45, pp. 141–152.

The author presents a method for evaluating the distribution of discharge in a network of pipes. The analysis, which is based on Kirchoff's laws, and which is similar to analyses of Fair and of Cross, consists of an iteration procedure. Formulas are developed for obtaining corrections to assumed distributions. Practical aspects of the problems are mentioned and examples are shown in detail. Glenn Murphy, USA

1021. **M. Craya, "Similitude in model rivers with fixed bottom"** (in French), *Houille blanche*, July-Aug. 1948, vol. 4, pp. 335–346.

This article includes a general discussion of the laws of similarity of fluid flow, together with several penetrating remarks on their application to the case of river flow. There is an argument for the legitimacy of using three different length scales in constructing a model for studying the mean flow of rivers, based upon the restriction to gradually varying flows and the control of the "roughness" parameter. Stephen H. Crandall, England

1022. **Georges Labaye, "Note on the transport of solids by watercourses"** (in French), *Houille blanche*, 1948, spec. no. A, pp. 600–627.

This paper is a thorough review of the subject of the transportation of solid materials by flowing water. For its length it is quite complete; unfortunately the sources of information are given only by mention of the author's name.

A discussion of the complexities of the problem and an indication of its world-wide importance is followed by discussions of the methods of bed- and suspended-load measurement. The various studies of and theories for bed-load movement are critically reviewed. The author notes that certain formulas are quite reliable in the domain in which they were derived but cannot be extrapolated because of the omission of the influence of certain fundamental parameters.

Suspended material transport is discussed with brief mention of colloidal suspension and density currents. The turbulence-diffusion theory for suspended material transport is covered rather thoroughly and need is shown for more definite information on the effect of turbulence on the falling velocity of isolated grains and the relation between the momentum-transfer coefficient and the diffusion coefficient for suspended material. The works of Lane, Kalinske and Hsia are quoted as giving the basic information on how material gets into suspension. J. M. Robertson, USA

Incompressible Flow: Laminar; Viscous

(See also Revs. 1030, 1035, 1055, 1056)

1023. **Ion Cârstoiu, "On certain formulas in the motion of a fluid"** (in French), *C. R. Acad. Sci. Paris*, Dec. 20, 1948, vol. 227, pp. 1337–1339.

This brief note gives extensions of the author's work exploiting the concepts of acceleration vector, vector curl of the velocity, vector curl of the acceleration, and the invariants of the infinitesimal transformations of these vectors. To read this paper it is necessary to see the preliminary material in *Bull. Sec. sci. Acad. Roum.*, 1946, vol. 29, p. 83 and p. 207.

Stephen H. Crandall, England

1024. **R. S. Rivlin, "The hydrodynamics of non-Newtonian fluids,"** *Proc. roy. Soc. Lond. Ser. A*, May 27, 1948, vol. 193, pp. 260–281.

The author's problem is to find the most general equations governing the motion of incompressible isotropic viscous fluids, and to discuss the phenomena they predict. Part A concerns kinematics; all results here were implied in one way or another by Cauchy, and most were worked out by Beltrami [*Opere*, vol. 2, pp. 202–379]. The author's general considerations are lengthened and encumbered by his eschewing tensorial notations and principles. Part B concerns the dynamics of "non-Newtonian" fluids, which are defined as continua in which the rate of dissipation of energy is a nonlinear function of constants of the material and of the rate of deformation d_j^i only. In the isotropic case, Reiner [*Amer. J. Math.*, 1945, vol. 67, pp. 350–362] showed that the most general relation giving the stress components T_j^i in terms of the d_j^i is

$$(*) \qquad T_j^i = -(p + \Xi)\delta_j^i + 2\Theta d_j^i + 2\Psi d_k^i d_j^k,$$

where p is the thermodynamic pressure and Ξ, Θ, and Ψ are power series in the principal invariants K_1, K_2, K_3 of d_j^i. In the classical theory of viscous fluids, which the author calls Newtonian, we have $\Xi = -\lambda K_1$, $\Theta = \mu$, $\Psi = 0$, where λ and μ are coefficients of viscosity. When the fluid is incompressible, $K_1 = 0$ and Ξ may be incorporated in p, which now is without thermodynamic significance. Dynamical equations may be obtained by substituting (*) into Cauchy's laws of motion.

The author states that boundary conditions on any one portion of the boundary may be of one of two types: either stresses or velocities may be prescribed. The former type secures uniqueness, but is not usual in hydrodynamics, where the reaction of the material upon solid boundaries is usually a major unknown. The author neglects to remark that except in the Newtonian (linear) case the differential equations for the velocities are of third or higher order, and hence prescribing the boundary velocities is not sufficient for uniqueness. (Reviewer's note: At the moment, discovery of the proper boundary conditions is the major block to further progress in nonlinear fluid dynamics, whether by continuum or by kinetic-theory methods. The author does not mention the possible dependence of Ξ, Θ, and Ψ upon the thermodynamic state, and does not mention the physical dimensions of any of his terms. It can be shown that the author's fluids possess two and only two independent dimensional moduli: a viscosity μ and a "natural time" t_0. They are thus basically different from those considered by the reviewer [*Proc. Nat. Acad. Sci. Wash.*, 1948, vol. 34, pp. 342–347, *Proc. 7th int. Congr. appl. Mech.*, forthcoming] in which no modulus t_0 occurs.)

In part C the author considers some special flows. First, in a steady flow between parallel plates, if $\Psi \neq 0$, there exist nonhydrostatic normal stresses in the direction of flow. Second, the torsional motion $u = -\psi yz$, $v = \psi xz$, $w = 0$, where ψ is a constant, is dynamically possible if the centripetal accelerations may be neglected, and the pressure may be adjusted so as to make the stresses vanish upon the cylindrical surface $x^2 + y^2 = a^2$. The resultant couple necessary to produce the motion for a given cylinder radius depends only upon Θ, while if $\Psi \neq 0$ a normal surface traction depending only upon Ψ must be exerted upon the plane ends $z = \pm b$. Thus, experiments measuring only the couple or only the normal traction yield information only about one or the other portion of the basic law (*). Finally, surface tractions necessary to produce a simple rotational vortex motion between two infinite coaxial circular cylinders are determined. Again, in addition to a torsional couple, also a normal surface traction is required if $\Psi \neq 0$. In the case when $\Theta = \text{const}$, $\Psi = \text{const}$, the sign of this normal stress depends upon the sign of Ψ. Similar properties were observed in a number of fluids by Weissenberg [*Nature Lond.*, 1947, vol. 59, p. 310] who proposed to describe them by a semiempirical law of elasticity; they are included by the author's theory of fluids in a fashion both more natural and more definite. C. A. Truesdell, USA

1025. **Ralph W. Powell, "Vedernikov's criterion for ultrarapid flow,"** *Trans. Amer. geophys. Un.*, Dec. 1948, vol. 29, pp. 882–886.

Vedernikov has developed a criterion for the stability of steady uniform flow. When the Vedernikov number is less than one, waves tend to dampen out; when it is equal to or greater than

one, they amplify so that steady flow is impossible and we have ultrarapid flow.

Some further mathematical developments on the Vedernikov number are given, and the criterion is compared with several others and is judged to be more comprehensive and exact. An empirical formula for Chezy's roughness factor C in ultrarapid flow is derived from experimental data already published by the author. Charles Jaeger, England

1026. W. Tollmien, "Asymptotic integration of the differential equation for perturbations of two-dimensional laminar flow at high Reynolds numbers" (in German), *Z. angew. Math. Mech.*, vol. 27: May 1947, no. 2, pp. 33–50; June 1947, no. 3, pp. 70–83.

This paper investigates the asymptotic solutions for large Reynolds number R of the differential equation for the stream function, $\varphi(y) \exp i\,\alpha(x - ct)$, of an infinitesimal disturbance in a plane laminar flow with a boundary-layer-like velocity profile, $U(y)$. The usual fourth-order equation for φ is approximated for large R by $U - c(\varphi'' - \alpha^2\varphi) - U''\varphi = \varphi''''/i\alpha R$. The asymptotic solutions are taken as the solutions φ_1 and φ_2 of the equation $(U - c)(\varphi'' - \alpha^2\varphi) - U''\varphi = 0$ (with some modification of the solution φ_2 in the neighborhood of the value of y, taken as 0, for which $U = c$, in order to avoid a singularity) and the solutions φ_3 and φ_4 of the equation $\varphi'''' - i\alpha R\,(U - c)\varphi'' = 0$ whose derivatives increase with increase of αR.

The paper is devoted chiefly to finding the form of the functions φ_1, φ_2, φ_3, φ_4 and their derivatives, and to estimating the difference between these functions and the corresponding exact solutions. The error estimates are given as functions of the parameter $\epsilon = (\alpha R U'_0)^{-1/3}$, and decrease as ϵ decreases. A large amount of detailed analysis is involved.

J. V. Wehausen, USA

1027. George Green, "Waves in deep water due to a concentrated surface pressure," *Phil. Mag.*, Sept. 1948, vol. 39, pp. 738–743.

The author applies a method described by Kelvin [*Proc. roy. Soc. Edinb. Sect. A.*, 1906, vol. 26, p. 412] to two problems of two-dimensional motion of water initially at rest under gravity: (1) the waves due to the application of a time-periodic surface pressure, (2) the waves due to a moving concentrated pressure applied for a time interval t. The author states that his result in the case of (1) disagrees with that given by Lamb [*Hydrodynamics*, 3d ed., Cambridge Univ. Press, 1905, pp. 375–377, but omitted in later editions]. This reference is not available to the reviewer, but the disagreement, here ascribed to Lamb's introduction of Rayleigh's dissipative forces, could explain its omission from later editions. In the case of the second problem Lamb gives the solution for $t \to \infty$ and this agrees with that found by the author for this case.

L. M. Milne-Thomson, England

Courtesy of Mathematical Reviews

1028. Victor P. Starr and George W. Platzman, "The transmission of energy by gravity waves of finite height," *J. mar. Res.*, Nov. 1948, vol. 7, pp. 229–238.

The authors derive mathematical formulas for the transmission of energy across a vertical plane, due to the arbitrary two-dimensional motions of a layer of ideal fluid under gravity, without the simplifying assumption of infinitesimal wave amplitude made in the classical theoretical treatment by Reynolds and by Rayleigh.

First, an expression is deduced for the rate of energy transfer in a fluid across an arbitrarily fixed vertical; this expression is called the energy-transmission function. The developed concepts and expressions are then applied to the case of periodic waves in a deep basin, and it is shown that the energy transmitted during one wave period is equal to twice the kinetic energy of the horizontal motions per wave length. Calculation of the ratio of the energy transmitted during one wave period to the total wave energy per wave length shows that the classical small-amplitude theory, according to which the ratio of transmitted energy to energy "density" equals one half, represents only a special case of the general theory developed by the authors.

The individual contributions to the transmission function of the advection of kinetic energy, the work done by pressure forces, and the advection of potential energy are examined and mathematically defined. It is found that the amount of potential energy transported by the wave motion in one wave period is equal to the amount of kinetic energy transported in the same period.

Hans F. Winterkorn, USA

1029. Joseph B. Keller, "The solitary wave and periodic waves in shallow water," *Commun. appl. Math.*, Dec. 1948, vol. 1, pp. 323–339.

After reviewing previous solutions of Scott Russell, Boussinesq, Rayleigh, Korteweg and DeVries, Gwyther, McCowan and Weinstein on solitary nonrotational waves in shallow inviscid water, the author arrives at the conclusion that there exists no systematic method for calculating these wave shapes to a given degree of approximation. He develops such a method, expanding the solution in terms of a dimensionless parameter $\alpha = (\omega h)^2$, where h is the depth of the undisturbed fluid and ω the curvature at some point on the surface, inserting the expansions into the equations of motion and the boundary conditions, and equating the coefficients of like powers of α. He then solves these equations for periodic and solitary waves of unchanging shape, through the first and second approximations. The latter involve elliptic functions and integrals. H. Poritsky, USA

Compressible Flow, Gas Dynamics

(See also Revs. 1050, 1053, 1060, 1065, 1072, 1074)

1030. H. Görtler, K. Wieghardt, H. Fromm, A. Betz, R. Sauer, M. Pinl, W. Spannhake, F. Schultz-Grunow, F. Reutter, and W. Barth, "Convention of German mathematicians in Karlsruhe, April 10-12, 1947. II. Fluid flow" (in German), *Z. angew. Math. Mech.*, Aug.-Sept. 1947, vol. 25/27, pp. 145–159.

In the first of this series of ten short summaries, Görtler discusses the growth of the laminar boundary layer on a cylinder at the start of its motion. The results of calculations and experiments on elliptic cylinders are described, having to do especially with the initial separation point, the time of initial separation, and the subsequent movement of the separation point. Good agreement is reported.

Wieghardt reports on some experimental investigations of turbulent boundary layers, which verify the one-parametric nature of the profile, even over various kinds of surfaces. The significance of an integral-energy equation analogous to von Kármán's momentum equation is also discussed.

Fromm has calculated laminar flows of a Maxwell fluid, in comparison with the usual Newton assumption. This is a fluid whose rate-of-strain tensor includes both rate-of-stress (viscous) and stress (elastic) terms. Fromm treats first steady plane flow of this type, and then parallel flow in a circular pipe. For example, in plane shear flow, the shear stress τ, as a function of rate of shear, reaches a maximum and then decreases with increasing

rate of shear. This suggests instability of the flow. The important physical parameter is the ratio of the viscosity coefficient μ to the elastic shear modulus G; in a Newton fluid we ordinarily put this ratio equal to zero.

Betz remarks briefly on a new proposal for the calculation of plane potential mixed flows, using the relations $[\ln(\rho v)]_s = -\vartheta_n$ and $(\ln v)_n = \vartheta_s$, where ρ, v, ϑ are density, flow speed, and flow direction; s and n are intrinsic coordinates along and normal to the streamlines. Application to the flow past a circular cylinder at a stream Mach number of 0.6 is described.

Sauer contributes some remarks on the theory of characteristics for second-order partial differential equations. He considers the case where the characteristic net (either before or after transformation by Legendre's transformation) is made up of straight lines, and finds that a closed-form solution can be written down. This is applied to the minimal-surface equation, the linearized equation of supersonic conical flow, and the nonlinear equation of plane-wave propagation with the ratio of specific heats equal to 3 or -1.

Based on unpublished work of H. Eichler, Pinl gives an integral-operator method of integrating equations of the form

$$\Delta U + A(x, y)U_x + B(x, y)U_y + C(x, y)U = 0.$$

This procedure results in the formal construction of a plane compressible adiabatic flow corresponding to every analytic function of a complex variable.

Spannhake's contribution is an approximate one-dimensional treatment of compressible isothermal flow in axisymmetric vaneless diffusers of small breadth.

To obtain a comparison between experiment and theory in a one-dimensional case of unsteady channel flow, Schultz-Grunow carries out a calculation, based on an acoustic approximation, for the periodic flow of air out of a pressure vessel with a rotating valve. In order to obtain agreement, he finds it necessary to introduce a Carnot-shock both for the partially open valve and for air flow into the channel.

Reutter considers an approximate method suggested by K. Oswatitsch for the calculation of plane adiabatic flow near the sonic speed. This is based on an approximate quadratic expression for the mass flow ρv, which leads to a simple nonlinear differential equation for a disturbance potential. An attempt to apply this to the flow about a symmetric profile apparently led to considerable difficulties.

In the closing contribution, Barth considers the flow of dust-carrying air through a Laval nozzle. If the dust particles move with the flow speed before the nozzle, they will lag, due to their inertia, as the air is accelerated in the nozzle. A simple theory is set up for this case, assuming spherical particles. An experimental check was carried out, and it is shown that the average size of particles can be correctly estimated from measurements of dust and air-flow rates, and the pressure drops with and without dust.

W. R. Sears, USA

1031. A. M. Feinzilber, "Reduction of equations for isothermal gas flows to quadratures" (in Russian), *Notes Acad. Sci. USSR (Doklady Akad. Nauk SSSR)*, Oct. 11, 1948, vol. 62, pp. 603–606.

This short note has as its object the proof that the equations of isothermal gas flow in some cases may be reduced to quadratures. This reduction is effected by the following two boundary conditions: no slip at the boundary and the conversion of viscous flow into an adiabatic flow.

L. M. Tichvinsky, USA

1032. K. Oswatitsch, "On the method of characteristics in hydrodynamics" (in German), *Z. angew. Math. Mech.*, vol. 25/27: Oct. 1947, pp. 195–208; Nov.-Dec. 1947, pp. 264–270.

The essential ideas which occur with the application of the method of characteristics to gas-dynamical questions are represented in a form which answers the needs of an engineer with mathematical experience but without a special knowledge of the field. The list of references does not cover the important literature which was classified during the war. G. Guderley, USA

1033. Knox Millsaps, "A note on one dimensional fluid dynamics," *CADO tech. Data Dig.*, Jan. 1, 1949, vol. 14, pp. 13-21.

The author states in his summary that the conventional treatment of one-dimensional gas dynamics, using the concept of a perfect gas, is extended to the more exact equations of state of Van der Waals and Beattie-Bridgeman. The conditions of flow of a point on a streamline are given in nondimensional form, in terms of an initial set of conditions and mass, momentum, and energy changes. It is noted that an unusual simplification occurs for perfect gases, and criteria are given for comparing the simplified case with more general equations of state.

M. G. Scherberg, USA

1034. Demetrios Samaras, "Contribution to the theory and performance of ram jets," *Nat. Res. Counc. Can. Aero. Rep.*, no. 3, 1948, pp. 1–23.

The author reviews the available literature and discusses briefly the general design requirements of both subsonic and supersonic ramjets. External and internal losses are considered, as well as the combustion process and possible fuels. A fundamental performance analysis develops a series of design charts for a Mach number range of 0.2 to 8.0, which plot specific fuel consumption times combustion efficiency versus specific thrust. It is concluded that for subsonic flight speeds, the over-all pressure efficiency (defined as exit to entry total-pressure ratio) is more important than combustion efficiency, while at supersonic speeds the opposite is true. W. C. Nelson, USA

1035. C. Ferrari, "Determination of the flow past a cascade of strongly curved airfoils" (in Italian with English abstract), *Aerotecnica*, June 1948, vol. 28, pp. 119–135.

The author attempts the solution of the problem of the flow past an airfoil cascade of turbines or axial compressors, without assuming incompressibility of the flow or small camber and small thickness of the airfoils.

In the first part of the paper the fluid is still supposed incompressible. An airfoil cascade is conformally transformed into a circle. A first transformation [studied by the author in *Aerotecnica*, 1947, vol. 27, p. 395] changes the cascade into a near ellipse, a second one (due to Joukovsky) changes the ellipse into a circle, and finally the method of harmonic analysis (due to von Kármán and Trefftz) leads to a circle in the presence of two vortices. The paper shows how the zero-lift angle, the optimum incidence angle, and the pressure distribution on each contour can be determined.

The method, though somewhat complicated, is simpler than the one due to Traupel [*Sulzer tech. Rev.*, 1945, no. 2]. It is applicable to any camber and thickness with the sole (but, apparently, essential) restriction of a zero angle at the trailing edge. It appears from the examples that a curvature increase is much more efficient (for the purpose of increasing lift at given incidence) for turbine, than for compressor blades, even if flow separation is neglected.

In the second part, the method is appropriately modified and

applied to compressible subsonic flows. The "rectilinear" isentropic approximation of von Kármán and Tsien is used, as well as a method of P. Germain [*C. R. Acad. Sci. Paris*, 1946] yielding nonvanishing circulation. Both parts of the paper are illustrated by numerical examples. Gino Moretti, Argentina

1036. Harold Mirels, "Theoretical method for solution of aerodynamic forces on thin wings in nonuniform supersonic stream with an application to tail surfaces," *Nat. adv. Comm. Aero. tech. Note*, no. 1736, Nov. 1948, pp. 1–25.

This method to correct for the influence of a slight nonuniformity of the stream on the aerodynamic characteristics of a wing is based on the linearized theory. The actual perturbation of the flow is represented by superimposing on the uniform flow U the gradient of the sum of three perturbation potentials $\varphi' + \varphi'' + \varphi'''$, φ' being the (given) "nonuniformity potential" of the stream, φ''' the potential characterizing the wing in the uniform flow U, and the potential φ'' arising from the necessity to cancel the nonuniformity component along the wing surface. The latter contribution is represented by continuous sources of strength $-w'/\pi$ and w'/π respectively, distributed over the upper and lower side of the wing. The corresponding pressure coefficients are given in form of integrals over certain portions of the wing edge and the wing area.

Lift and moment corrections for a rectangular wing (tail surface) in downwash fields with given parabolic and linear (spanwise) w' distributions are worked out for aspect ratios larger than $2(M^2 - 1)^{-1/2}$.

G. Kuerti, USA

1037. J. Ackeret and N. Rott, "On the flow of gases through unstaggered gratings with symmetric profiles," (in German), *Schweiz. Bauztg.*, 1949, vol. 67: Jan. 15, pp. 40–41; Jan. 22, pp. 58–61.

An account is given of high-speed wind-tunnel experiments with an unstaggered grating consisting of symmetric profiles. The ratio t/l, where t is the spacing between the profiles and l their length, was varied in the experiments. The values of blocking speeds (choking speeds) and maximum drag coefficients obtained agree well with theoretical values. Theoretical maximum drag occurs when supersonic flow is established in the diverging part of the channel, setting up unsymmetry in the pressure field. The results show that the latter plays the major part in the sudden increase of resistance of blocking speed; they also demonstrate certain advantages of thin profiles.

Reference is made to the use of the hydraulic analogy for studying incident speeds above the blocking speed; the flow is then unsteady and a shock wave runs ahead of the grating. Consideration of the way in which the distance of the shock wave from the grating depends upon the rate of change of velocity leads to the idea that the very large distance between shock wave and projectile observed in certain flight photographs may result from the unsteadiness of the flow through the sonic region; a means of detecting the effect is suggested. D. C. Pack, Scotland

1038. J. M. Richardson, "Hydrodynamic properties of sea water at the front of a shock wave," *J. chem. Phys.*, Nov. 1947, vol. 15, pp. 785–794.

Theoretical and experimental investigations on shock waves in fluids are based on the Rankine-Hugoniot equations which set forth certain conditions which must be satisfied at the shock front. These equations express the condition of conservation of mass, momentum and energy at the front and they lead to expressions giving the velocity U of the shock front, and the discontinuity in the values of particle velocity u and of the specific enthalpy ΔH at the front in terms of the excess pressure p at the front and the specific volume v of the medium at this pressure.

Here, the aim of the author is to determine the numerical values of U, u and ΔH as a function of p for sea water at specified temperatures between 0 and 40 C, and at certain values of salinity. For this purpose, specific heat and compressibility data and the various equations of state for sea water are surveyed critically, for pressures between 0 and 80 kilobars, and the most probable values are deduced for use in calculating the numerical values of U, u and ΔH. The results of the calculations are given in the form of two sets of tables—a long-range, large-increement set for $0 \leq p \leq 80$ kilobars, and a short-range, small-increement set for $0 \leq p \leq 14$ kilobars. R. M. Davies, Wales

1039. L. A. Galin, "Impact on a rigid body resting on the surface of a compressible fluid" (in Russian), *Appl. Math. Mech. (Prikl Mat. Mekh.)*, Sept.-Oct. 1947, vol. 11, pp. 547–550.

A rigid body of mass m and length l strikes the surface of a compressible fluid of density ρ with velocity v_0 normal to the fluid surface, initially at rest. On the assumption of a scalar potential function $\phi(x, y, t)$, the normal stress and the displacement v in the y-direction will be respectively $\sigma_y = \lambda(\phi_{xx} + \phi_{yy})$ and $v = \phi_y$. $\phi(x, y, t)$ will be a solution of the wave equation $\phi_{xx} + \phi_{yy} - (\rho/\lambda)\phi_{tt} = 0$ where λ is the Lamé constant, and the second Lamé constant μ equals zero.

For the time interval $0<t<(l/2)(\rho/\lambda)^{1/2}$, the author finds the exact solution for the motion of the rigid body after impact to be

$$y = (\rho/\lambda)^{1/2}\,[\exp\,[a_1(\lambda/\rho)^{1/2}t] - \exp\,[a_2(\rho/\lambda)^{1/2}t]]v_0(a_1 - a_2)^{-1}$$

where $a_1, a_2 = l\rho/2m \pm [(l\rho/2m)^2 - \rho/m]^{1/2}$. The force on the body in this time interval will be $F = m\ddot{y}$.

For $(l^2\rho/4m)>1$, the force on the body will continuously increase during the specified interval; for $(l^2\rho/4m)<1$, the force may change sign, with consequent rebound of the body from the fluid. John M. Kopper, USA

1040. Michel Luntz, "Molecular aerodynamics" (in French), *Rech. aéro. Paris*, Jan.-Feb. 1949, no. 7, pp. 17–33.

After a brief discussion of the cases where conventional fluid mechanics based upon the Navier-Stokes equations is not applicable, the author gives a rather extended exposition of the elements of the kinetic theory of gases. The interaction of the gas and a moving wall in the free-molecular flow case is then treated, following the calculations by Sänger and Bredt, and Tsien [*J. aero. Sci.*, 1946, vol. 13, pp. 653–664; 1948, vol. 15, pp. 573–580; see Rev. **256**, Feb. 1949]. The paper concludes with numerical results for the following specific examples under the assumption of completely diffuse reflection of the molecules and unit accommodation-coefficient: (1) insulated flat plate without radiation heat loss; (2) heat-conductive flat plate without radiation; (3) drag of a cone without radiation; and (4) drag of elliptic cylinders and spheres. H. S. Tsien, USA

1041. M. Heineman, "Theory of drag in highly rarefied gases," *Commun. appl. Math.*, Sept. 1948, vol. 1, pp. 259–273.

The mechanism of drag in highly rarefied gases is examined from a kinetic-theory point of view. For free-molecular flow the drag is controlled entirely by the nature of reflection of molecules from the surface of the moving body. After examining the present state of knowledge of reflection phenomena, formulas for the drag are derived assuming specular and diffuse reflection. Curves are

presented showing the variation of drag with Mach number for a flat plate at various angles of attack, a sphere, a cylinder, cones of various cone angles, and an ellipsoid. An attempt is made to improve this theory, assuming as a second approximation that molecules might strike the surface twice, separated by a molecule-molecule collision. Formulas for this last case are developed but no specific results are obtained except for a flat plate moving normal to itself at very high speed. Howard W. Emmons, USA

Turbulence, Boundary Layer, etc.

(See also Rev. 1030)

1042. **Busuke Hudimoto, "On converging and diverging flows"** (in Japanese), *Trans. Soc. mech. Engrs. Japan*, 1948, vol. 14, no. 48, part 3, pp. 1–4.

The author considers two problems arising from his measurements on turbulent flow in converging and diverging channels. First, it is suggested from the velocity distribution that a laminar sublayer becomes thicker in converging flows, especially when the pressure drop is large. The effect is explained by a simple calculation, in which both viscous and turbulent stresses are considered and Prandtl's mixing length is assumed to be proportional to the distance from the outer edge of the laminar sublayer. Second, it is pointed out that the pressure recovery in a diverging channel of rectangular section depends not only on the angle between the walls but also on the breadth-width ratio of the section. This is again explained by a simple boundary-layer calculation.

Itiro Tani, Japan

1043. **A. Fage and W. G. Raymer, "Note on empirical relations for a turbulent boundary layer,"** *Rep. Memo. aero. Res. Counc. Lond.*, no. 2255, Mar. 1946 (issued in 1948), 8 pp.

The von Doenhoff-Tetervin method ["Determination of general relations for the behavior of turbulent boundary layers," *Nat. adv. Comm. Aero. Rep.*, no. 772, 1943] and the Garner method ["The development of turbulent boundary layers," *Rep. Memo. Aero. Res. Counc. Lond.*, no. 2133, 1944] are compared. It is shown that there is an appreciable difference between the pressure distributions required by the two methods in order that the turbulent-boundary-layer velocity-profile-shape parameter be the same at all positions on the surface of a body.

Neal Tetervin, USA

1044. **Robert Legendre, "Note on the distribution of mean velocities for turbulent flow in cylindrical ducts"** (in French), *Houille blanche*, 1948, spec. no. A, pp. 579–583.

In a previous paper [*France Energ.*, July-Aug. 1946] the author showed that the approximate von Kármán law of velocity distribution in turbulent tube flow can be obtained by combining two laws, one valid near the wall, the other near the axis of the tube. To improve on this approximation, the author proceeds from the very accurate measurements of J. Nikuradse [*Forschungsh. Ver. dtsch. Ing.*, 1932, no. 356; summary in Bakmeteff, *Turbulence*, Paris, Dunod, 1941].

For large Reynolds numbers, the only ones here considered, the tube resistance $-\partial p/\partial x$ is best expressed in the terms of the shearing-stress velocity u_*, $u_*^2 = -R\,(\partial p/\partial x)/2\rho$. The viscosity ν is introduced through the inverse Reynolds number $\epsilon = \nu/2u_*R$. A well-known momentum theorem, putting $y = r/R$, leads to the equation $y = \overline{uv}/u_*^2 - 2\epsilon(d\bar{u}/dy)/u_*$, from which $\overline{uv}/u_*^2$ can be obtained, using the measurements. According to these, the formula $\bar{u} = u_{\max} - \phi(\epsilon)u_*(1-y)^{3/2}$ is quite accurate near the tube axis. For a larger domain, extending as far as the region of validity of the wall flow, it is true that, for a fixed value y_0, $[\bar{u}(y,\epsilon) - \bar{u}(y_0,\epsilon)]/u_* = f(y,\epsilon)$.

According to experimental results, $f(y,\epsilon)$ is practically equal to $f(y,0)$, hence also $d(\bar{u}/u_*)/dy = f_y'(y,0)$. In the laminar layer at the wall, we have $\nu d\bar{u}/Rdy = -u_*^2$ or $d\bar{u}/u_* = -dy/2\epsilon$. For this reason the author introduces a new variable into the wall law, namely, $z = (1-y)/2\epsilon$, and writes $\bar{u}/u_* = g(z,\epsilon)$. As a basis for his further calculations, he takes from the measurements the second y-derivatives of $f(y,0)$ and z-derivatives of $g(z,0)$ and finds that, near the wall, $f''(y,0) = -1/k(1-y^2) = -1/4k\epsilon^2z^2$ and $g''(z) = -1/kz^2$.

Integration, near the wall, leads to von Kármán's logarithmic law. The integration of Nikuradse's law leads to difficulties near the axis if $\epsilon \to 0$. It is reasonable to assume that for very small ϵ (large Reynolds numbers) the curvature remains finite for $y = 0$. In the pertaining discussion, unintelligible to this reviewer, there appears a constant $A = 2u_*/R$. The final formula for the velocity is

$$u/u_* = A - 2\beta\ln(\epsilon/\epsilon_0) + 2.5\ln(1-y) - 0.6\,y\ln y - [0.9 - 0.3\ln(\epsilon/\epsilon_0)]y,$$

where ϵ_0 is the value of ϵ in Nikuradse's sequence of experiments for $Ru/\nu = 105{,}000$, and where A is supposed to be derived from experiment. No definition of β is provided.

The formula $U/u_* = A - 4.2 - 2.6\ln(\epsilon/\epsilon_0)$ is given for the mean velocity U. The abscissa y_1 for $\bar{u}(y,\epsilon) = U(\epsilon)$ is approximately $y \approx 0.77 - 0.03\log_{10}(\epsilon/\epsilon_0)$. A full-page diagram shows the dependence of $d(\bar{u}/u_*)/dy$ on y, with the integral curves. These fail near the wall, and do not apply to the region near the axis. L. Prandtl, Germany

1045. **H. P. Schmitz, "On the change of the energy of turbulence"** (in German), *Z. Met.*, Nov. 1948, vol. 2, pp. 338–339.

The energy balance of atmospheric turbulence is treated under the assumption that turbulent energy transport can be expressed, in analogy with viscous dissipation, in terms of a diffusion coefficient η. In the absence of viscous dissipation the energy taken away from the main flow is spent partly to increase the kinetic energy of turbulence, and partly in lifting mass through turbulent mass transport. Leslie S. G. Kovasznay, USA

1046. **Carl Eckart, "An analysis of the stirring and mixing processes in incompressible fluids,"** *J. Mar. Res.*, Nov. 1948, vol. 7, no. 3, pp. 265–275.

Although mixing phenomena are important in numerous engineering fields, they are not well understood. Since this paper materially enriches both our conceptual and our theoretical knowledge of these phenomena it should be widely useful.

Two processes, stirring and mixing, are distinguished, which affect the mixture of fluids whose temperature θ_1 or concentration θ_2 is not uniform. Stirring is the advective process of laminar shear flow which alters the intimacy of contact between fluid elements of different θ_i. Mixing is the diffusion process which occurs if $\nabla\theta_i$ is different from zero. The stirring action is illustrated by an example of an eddy in which the mean value of $|\nabla\theta_i|$ increases as the first power of the time.

When the history of a volume V of incompressible fluid is considered that is bounded by a surface Σ inscribed in the fluid, the author shows that the rms gradient G [$G^2 = \int\int\int (\nabla\theta_i)^2\,d\tau$] changes according to the equation $G(dG/dt) = -\varkappa_i I^2 - S$. Here $\varkappa_i$ is the diffusivity; I, the rms value of $\nabla^2\theta_i$, is a measure of the inhomogeneity of the fluid; and

$$S = \int\int\int(\partial u_i/\partial x_j)(\partial\theta/\partial x_i)\,(\partial\theta/\partial x_j)d\tau$$

is a measure of the rate at which stirring decreases the mean gradient. If both $\partial\theta_i/\partial t$ and $\nabla\theta_i$ are different from zero in any part of Σ, a term must be added to the equation for (dG/dt). It is clear that diffusion always tends to decrease G.

The role of S needs to be examined further. Since

$$(\partial u_k/\partial x_j)(\partial\theta/\partial x_k)(\partial\theta/\partial x_j)$$

is shown to be independent of the curl of the velocity field u_i, the mixture process is not dependent upon generation of vorticity by viscous action, and indeed will usually be decelerated by such action. The advection corresponding to S may either increase or decrease the gradients, as the author illustrates by considering a simple shear flow. Ultimately, however, advection generally will decrease the gradient. Because examples such as small, exactly periodic surface waves provide exceptions to this rule, the author states that a general proof of the proposition will be analogous to the proof of the ergodic theorem, and will be difficult.

Bruce L. Hicks, USA

Aerodynamics of Flight; Wind Forces

(See also Revs. 965, 1036, 1061)

1047. William S. Aiken, Jr., "Standard nomenclature for airspeeds with tables and charts for use in calculation of airspeed," *Nat. adv. Comm. Aero. Rep.*, no. 837, 1946 (issued in 1949), 19 pp.

This report contains symbols and definitions of various airspeed terms which have been adopted as standards by the NACA Subcommittee on Aircraft Structural Design. Equations, charts and tables necessary for the evaluation of true air speed, calibrated air speed, equivalent air speed, impact and dynamic pressures, and Mach and Reynolds numbers are also included in this report.

Tables of the standard atmosphere to an altitude of 65,000 ft and a tentative extension to 100,000 ft are also included.

B. H. Edelman, USA

1048. Donald J. Graham, Gerald E. Nitzberg, and Robert N. Olson, "A systematic investigation of pressure distributions at high speeds over five representative NACA low-drag and conventional airfoil sections," *Nat. adv. Comm. Aero. Rep.*, no. 832, 1945 (issued in 1949), 68 pp.

Pressure distributions and section characteristics are presented for two low-drag airfoils and three conventional airfoils and are studied with reference to the effect of these characteristics upon performance, stability and control at high speed. It appears that the low-drag airfoils which were tested would provide improved airplane stability and control characteristics at supercritical speeds but are only slightly better than the conventional airfoils as regards drag characteristics at supercritical speeds. It is shown also that the von Kármán-Tsien compressibility relation may be used satisfactorily in predicting pressure distributions at Mach numbers where the local velocities over the airfoil are entirely subsonic.

John E. Goldberg, USA

1049. Harold H. Sweberg and Richard C. Dingeldein, "Summary of measurements in Langley full-scale tunnel of maximum lift coefficients and stalling characteristics of airplanes," *Nat. adv. Comm. Aero. Rep.*, no. 829, 1945 (issued in 1949), 36 pp.

This report presents an extremely useful summary and analysis of the results of full-scale wind-tunnel tests on the maximum lift and stalling characteristics of eighteen military airplanes of widely varying types. The tests include both lift-force measurements and tuft studies showing the development of the stall over various portions of each airplane as the angle of attack is increased.

The series of airplanes considered gives a wide variation in such geometric characteristics as wing aspect ratio, taper and sweepback. The effects of twist and spanwise variations in camber are also included. The effects of flaps, surface roughness, wing leakage, duct and armament installations, and propeller slip stream are considered.

The data presented are sufficiently comprehensive to enable the problems associated with poor stalling characteristics to be minimized, if not entirely eliminated, in preliminary designs, provided careful attention is given to detail design. This report should be of great value in the development of airplanes with initially good stalling characteristics, thus avoiding the necessity for the patchwork solutions frequently incorporated as afterthoughts in past designs.

M. J. Thompson, USA

1050. J. H. Greidanus and A. I. van de Vooren, "Gust load coefficients for wing and tail surfaces of an aeroplane" (in English), *Nat. LuchtLab. Amsterdam Rap.*, no. F.28, Dec. 12, 1948, 28 pp.

The report presents the results of extensive calculations of gust loads on an airplane. A wide range of the most important parameters was investigated in twenty-two cases. Although the computational details, and derivations of formulas have been omitted, all the basic assumptions are given and discussed.

The results are presented as curves of aerodynamic and inertia-load coefficients for wing and tail, as functions of eight parameters. It was found that, to a good approximation, the maximum values of the wing-load coefficients depend only on three of these parameters; the maximum values of the tail-load coefficients, however, depend on all but one.

It is proposed to publish the analysis, upon which the present work is based, in a separate report.

Louis Landweber, USA

1051. A. I. van de Vooren, "Loads on wing and tail surfaces of an aeroplane due to a sinusoidal gust wave" (in English), *Nat. LuchtLab. Amsterdam Rap.*, no. F.33, June 10, 1948, 20 pp.

The present report gives gust-load coefficients for the wing and tail for the case of a single sinusoidal gust wave. The rotation of the airplane about its lateral axis and the aerodynamic lag due to unsteady flow have been taken into account. Besides the length of the gust wave, two other parameters with predominating influence on the resulting loads have also been varied. One of the parameters is the slope of the pitching-moment coefficient, the other a coefficient C which unfortunately is not defined in this report. The results are combined with those of constant gusts with small initial gradients. Data for the latter, as well, as the method and mathematics, have been presented in two previous reports [J. H. Greidanus and A. I. van de Vooren, "Gust load coefficients for wing and tail surfaces of the aeroplane," *Nat. LuchtLab. Amsterdam Rap.*, no. F.28; A. I. van de Vooren, "Remarks on formulae and numerical methods used in the gust load calculation of report F.28," *Nat. LuchtLab. Amsterdam Rap.*, no. F.29].

Karl Arnstein, USA

1052. A. J. Marx and J. Buhrman, "Assisted control" (in Dutch with English summary), *Nat. LuchtLab. Amsterdam Rap.*, no. V.1398, Feb. 17, 1947, pp. 1–20.

The report gives an excellent survey of the influence of a spring tab on the control forces and the longitudinal stability of an airplane. Under consideration of the usual arrangement of a spring-tab control, the boost ratio of control forces is derived, assuming that the hinge-moment derivatives are constants. Besides the in-

fluence of design properties as given by the spring ratio and the gearing factor, the boost ratio shows the essential effect of this control device, for it is affected by speed in such a way that the largest reduction of control forces occurs at high speeds.

Particular attention is paid to the application of the spring tab to the statically balanced elevator. Equations are derived representing the relation between the stick force P and the dynamic pressure q in steady symmetric flight for the normal elevator as well as for the elevator with spring tab. The relation is a linear one in the case of a normal elevator, and has a hyperbolic characteristic for an elevator with spring tab. In consequence there is a change of the stick-force stability dP/dq with speed in such a way that dP/dq becomes very small at high speeds.

A discussion of the effect of changes in the hinge-moment derivatives shows that in unfavorable cases the application of a spring tab leads to a negative value of the stick-force stability.

Furthermore, the authors calculate the change in stick-force stability due to a displacement of center of gravity combined with such a change in tail-plane setting that the airplane is trimmed out for the original speed. It appears that in normal cases the change of stick-force stability is less for the elevator with spring tab. Investigations corresponding to those for steady symmetric flight were made for the case of a true-banked turn. The stick force may be resolved into two components, one of which occurs in steady symmetric flight. The second portion is proportional to a parameter Δn which is closely connected with the load factor. In the case of a normal elevator it is unaffected by speed. For an elevator with spring tab this maneuvering stick force decreases with speed, which leads to the possibility of overloading the airplane in turns at high speeds.

The important question of flutter is deferred to a special investigation. Ernest Eujen, Germany

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 981, 982)

1053. S. N. Karp and H. Weil, "The oscillating airfoil in compressible flow," *Hdqtrs. Air. Mat. Comm. Dayton Tech. Rep.*, no. F-TR-1195-ND, June 1948, 43 pp.

This monograph presents a systematic and clear development of the theory of nonstationary compressible isentropic flow as applied to the calculation of time-dependent forces acting upon an airfoil at subsonic and supersonic speeds. For the specialist it integrates, elaborates and arranges in an intelligible form results that were originally only briefly sketched in technical reports written in the Italian and German languages. To others it offers a lucid presentation of an interesting and involved technical subject both from a physical and a mathematical point of view.

At the beginning the acceleration potential is introduced and discussed. The fundamental differential equation, valid for both subsonic and supersonic linearized airfoil theory, is derived and expressed in terms of the acceleration potential and the free-stream Mach number. Since the boundary conditions differ for subsonic and supersonic flows, each of these is individually treated in separate chapters.

The subsonic case is treated by reducing the basic equation to an essentially time-independent wave equation for the acceleration potential. This is accomplished by assuming harmonic oscillations. This assumption does not in principle restrict the generality of the solution, since the harmonic oscillations can be used as components in a Fourier analysis of a general motion. Boundary conditions are then carefully discussed from various points of view. The equation is reduced to Bessel's equation of zero order and a solution satisfying prescribed boundary conditions is found. A constant appearing in this solution is related to the lift.

The integral equation for the pressure distribution is derived by relating the downwash velocity to the acceleration potential. Possio's method for deriving this equation is discussed and compared. A solution to the integral equation is then obtained by considering both Shades's and Dietze's method for isolating the singularity of the kernel of the equation.

The boundary conditions defining the supersonic case are considered in some detail and then formulated mathematically. Various methods for solving the resulting equation are proposed and evaluated. Among these are a method due to Riemann, the method of distributed sources and sinks, Heaviside's method, and the method of discontinuous functions. A formula for the lift distribution is then obtained. Results corresponding to a harmonically oscillating wing are given. Formulas for numerical calculations are also contained in the monograph. This work is an extremely good example of the importance of interplay between physical and mathematical considerations for obtaining results of practical value to aeronautical engineering. A list of 37 references is included. Paul Lieber, USA

1054. T. Ivaldi, "Note on the vibration phenomenon of an airplane tail and on the calculation of the relative critical velocity" (in Italian with English summary), *Aerotecnica*, June 1948, vol. 28, pp. 136–144.

A mathematical solution of the flutter problem for the horizontal tail of an airplane is derived under several simplifying assumptions. The fuselage is assumed to be built in at the rear spar of the wing. Two degrees of freedom are admitted: fuselage vertical bending and elastically restrained elevator rotation. The air forces are derived from two-dimensional theory by introducing correction factors indicated by available experiments.

The influence of various geometrical and structural parameters on the critical speed is examined and discussed. Details of the analysis, including a detailed examination of the vibratory motion, are given in three appendixes.

It may be observed that the title of the English abstract erroneously uses the expression "tail buffeting" instead of "tail flutter." F. J. Plantema, Holland

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 1016, 1035)

1055. Raymond Siestrunck, "The modern development of the theory of air screws" (in French), Gauthier-Villars, Paris, 1947. Paper, 9.9 × 6.5 in., 102 pp., 30 figs.

This is a treatise on the vortex theory of lightly loaded propellers. The first chapter is a discussion of the simplifying assumptions, such as the neglect of distortion of the free-vortex trail, and disposes of both viscosity and compressibility. There follows a chapter on the induced velocities due to free vortices, beginning with a single helical vortex, for which the integrals are set up but not evaluated. The case of several blades is handled by superposition of these integrals and evaluation of the velocities in Fourier-series form. Finally the simplification of infinitely many blades is presented. The calculation of conditions at the blades is carried out next; a considerable bibliography accompanies this chapter.

The longest chapter of the book is devoted to the problem of the optimum propeller. Betz's well-known result is derived by a more elegant argument than is usual. Prandtl's approximate solution for the optimum load distribution follows, and another approximation for very large advance ratios. Goldstein's exact solution is also presented in some detail.

The final chapter is concerned with application of this body of theory to propeller design, and a number of charts are included for this purpose. W. R. Sears, USA

1056. L. A. Dreyfus, "A three-dimensional theory of turbine flow and its application to the design of wheel vanes for Francis and propeller turbines" (in English), *Acta Polyt.*, 1947, no. 1, pp. 1–113.

In this paper, published by the Royal Swedish Academy of Engineering Sciences, a thorough investigation is made of the flow of water through pressure turbines and of the hydrodynamics of the runners. The theory develops and applies the differential equations of fluid motion in three dimensions under the assumption of thin vanes symmetric about the axis, and of a nonviscous incompressible fluid. It leads from well-justified fundamentals to the design of the surface of the wheel vanes, using a combination of graphical and analytical methods.

The third dimension, meaning in this case the angular position of the streamlines within the bucket area, is kept always in the picture; but the two-dimensional theory of Lorentz and his successors holds its own as a basic part of the new and more inclusive theory. One main difference is that divergences are discovered between solutions which would appear equivalent for a two-dimensional theory.

A few examples (including that of a partly open gate) are worked, in order to illustrate the method. However, no scheme of routine working is developed and no tables are set up for turbine dimensions, vane shapes, etc. The author hopes that the theory will be welcomed and further applied "by a younger generation always keen on surpassing the preceding one."

It is mentioned that this paper is but the first step toward a highly developed three-dimensional method of turbine design. Omitted is a treatment of discontinuities of terminal conditions at the entering and leaving vane edges. The phenomena thus neglected are distinctly local and affect only the definite shape of the edges, but not the rest of the vane surfaces bounding the buckets. The edge effects are to be treated by the author in a later paper using the theories of "wings" and "gratings," the latter being a new contribution to the methods of conformal transformation.

Although not mentioned, there should be a possibility of applying this method of Dreyfus to such cases of fluid flow as liquid clutches, torque converters, gas turbines, etc. The author gives enough references to his previous writings to convince the reader that he has done a great deal of work in the field of hydraulic turbines. W. C. Johnson, Jr., USA

1057. D. G. Ainley, "Performance of axial-flow turbines," *Proc. Instn. mech. Engrs.*, 1948, vol. 159, no. 41, pp. 230–244.

This paper gives a survey of experimental work carried out to clear up a number of poorly known factors affecting the design of gas-turbine stages. The following factors were investigated by means of blade-cascade and stage tests: maximum attainable efficiencies for different degrees of reaction and deflections, influence of blade-profile forms and blade pitching, influence of Mach and Reynolds numbers on the performances, secondary losses due to tip clearance and different distributions of the circulation as a function of the radius, etc.

The results of the tests are illustrated by numerous curves. The cascade losses are always smaller for reaction blading than for impulse blading. The losses of both reaction and impulse-type bladings are not appreciably affected by the Mach number, whereas big increases in profile losses are encountered when the Reynolds number falls off below 10^5. The results of the stage tests seem to show that the secondary losses are higher for impulse stages than for reaction stages. The stage efficiencies are always higher for reaction bladings. To conclude the paper a brief description of the technique adopted for full-scale testing of turbines is presented. E. Haenni, USA

1058. Osamu Nagano, "Thermodynamic method for the computation of the axial-flow air compressor" (in Japanese), *Trans. Soc. mech. Engrs. Japan*, 1948, vol. 14, no. 47, part 2, pp. 8–17.

The author assumes that, at each phase of compression, the increase of enthalpy di is accompanied by the generation of heat dq due to friction and other effects, and that $(di - dq)/di = \eta_s$ is constant throughout the compression. Denoting by p_1, T_1 and p_2, T_2 the pressure and the temperature before and after the compression respectively, and by T'_2 the temperature when the air is compressed to p_2 adiabatically, the author obtains a formula which determines the relation between η_s, $(T'_2 - T_1)/(T_2 - T_1)$ and p_2/p_1. This relation is useful for the estimation of the efficiency when a compressor is used under various working conditions. The relation between η_s and the polytropic index is also obtained. Subsequently, a method for calculating η_s by the wing theory is presented. Corrections to η_s for the leakage at the tip of the blade and the friction at the wall are considered. Finally, a practical method for designing the compressor is explained. Humio Tamaki, Japan

1059. Robert C. Kohl, Howard Z. Herzig, and Warren J. Whitney, "Effects of partial admission on performance of a gas turbine," *Nat. adv. Comm. Aero. tech. Note*, no. 1807, Feb. 1949, pp. 1–76.

It is shown in this paper that the partial-admission performances of single-stage gas turbines can be closely evaluated by measuring the performances at full admission and at one degree of partial admission. In addition to the normal full-admission losses two categories of losses are encountered at partial admission: pumping losses in inactive rotor blading and driving-fluid losses (scavenge, eddy and diffusion losses). Both these losses are closely proportional to the amount of active nozzle reduction.

According to the test results carried out on a commercial jet-engine turbine, the pumping losses increase approximately as the third power of the rotor speed, whereas the driving-fluid losses can be assumed to vary linearly with the rotor speed. The tests were carried out for three degrees of admission. The power outputs and total efficiencies for other degrees of admission were calculated by using the above-mentioned rules. The accuracy was checked by calculating partial-admission performances for one of the measured degrees of admission with the aid of the experimental values of the other measured degree of admission. The calculated values are within one to three per cent of the test values.

Turbine-power reduction by means of nozzle cut-out is compared with other methods (inlet pressure, pressure ratio and rotor-speed variation). It is shown that the partial-admission regulation has a high degree of flexibility, while up to 180-deg nozzle reduction the efficiencies are comparable to the values reached with the other methods.

The problem of blade vibrations due to nozzle cut-out is discussed briefly. E. Haenni, USA

Flow and Flight Test Techniques

(See also Revs. 970, 1071)

1060. Hans-Joachim Kanold, "Comments on the directiona sensitivity of the Prandtl tube in the measurement of static pressure" (in German), *Z. angew. Math. Mech.*, July 1947, vol. 25/27, pp. 124–126.

This paper gives a theoretical calculation of the deviation of the static pressure indicated by a Prandtl tube at different inclinations to the air stream. Three cases were calculated: (1) the static-pressure orifice in the form of a continuous circumferential slot; (2) a continuous slot over one half the circumference; and (3) individual holes of finite number greater than 2, symmetrically arranged. The calculations show that the theoretical formula is the same for all three cases. Comparison of the calculations with measurements shows good agreement up to an inclination angle of 20 deg. Discrepancies for angles greater than this value are explained by separation.

Frank L. Wattendorf, USA

1061. **Gerald G. Kayten, "Analysis of wind-tunnel stability and control test in terms of flying qualities of full-scale airplanes,"** *Nat. adv. Comm. Aero. Rep.*, no 825, 1945 (publ. in 1948), pp. 1–19.

It is suggested that in many cases the results of wind-tunnel tests of models of aircraft are not presented in a manner that would best demonstrate the stability and control characteristics that are of immediate interest to the designer. The paper discusses each of the present NACA requirements for satisfactory flying qualities, and illustrates by means of representative graphs how wind-tunnel test data should be analyzed and presented, so that the degree to which the aircraft may be expected to meet these requirements can be most readily determined. It is suggested that such a procedure may also help to indicate in general what revisions or modifications of the present requirements may be desirable from time to time.

Problems of scale effect in interpreting wind-tunnel data are not discussed in any detail, and the paper excludes the special problems associated with high-speed aircraft.

A. D. Young, England

1062. **R. Betchov and E. Kuyper, "An amplifier for the study of the turbulence of air flow"** (in French), *Proc. kon. Ned. Akad. Wet.*, Nov. 1947, vol. 50, pp. 1134–1141.

The authors, after giving the general principles of hot-wire measurement and its theory (based on the linear law of heat exchange introduced by King), state that without special provisions fluctuations of the flow are reproduced by the alternating voltage with a phase lag and a reduction of the amplitudes. They then describe an amplifier compensating these effects. A complete diagram of the electric equipment is added. The arrangement permits the measurement of the turbulence, and the correlation coefficient. Wilhelm Spannhake, USA

1063. **P. Fayolle and P. Naslin, "High-speed photography and motion pictures"** (in French), *Mémor. Artill. fr.*, 1948, vol. 22, no. 3, pp. 657–755.

The paper covers both the optical and photographic problems of high-speed observational methods. General equations and performance characteristics are given for strioscopic methods (schlieren, Toepler-Foucault, etc., interferometric methods and high-speed photoelastic work). Also covered is the question of high-speed sources, such as arc, spark, X-ray, and the various methods using shutters such as Kerr cells, and pulsed electron optical image converters. More than eight pages are devoted to the question of synchronization.

Among the miscellaneous subjects covered are stereoscopic methods, installation for successive pictures along a trajectory, and the production of four-microsecond high-intensity flashes by shock compression of air or gases such as argon.

Inasmuch as the wide field of related subjects covered is accompanied by derivation of the related equations, the paper is unique as a survey of a field where published papers are widely scattered and generally lacking in a quantitative approach. In view of the survey nature of the paper, the absence of many intermediate steps in some of the derivation is presumably justified. Typographical errors apparently cause confusion in a few equations.

The use of electron optics for shuttering, in the form of wartime infrared image converters, is novel to the reviewer. The concept is capable of considerable use in the observation of self-luminous phenomena and opaque objects not permitting strioscopic study. The concept may be considered analogous to the Kerr cell with the exception of the possibility of considerably greater convenience at the expense of possible loss of resolution.

This paper, in conjunction with the special "High-Speed Photography" supplement to the March 1949 issue of the *Journal of the Society of Motion Picture Engineers*, constitutes a very complete survey of the field. Robert E. Lewis, USA

Thermodynamics

(**See also Revs. 1034, 1040, 1041, 1057, 1058, 1059**)

1064. **J. H. Hildebrand, "The entropy of solution of molecules of different size,"** *J. chem. Phys.*, May 1947, vol. 15, pp. 225–228.

The entropy change in mixing two liquids whose molecules differ in size is expressed by the following equation:

$$\Delta S/R = N_1 \ln[(V - N_1 b_1 - N_2 b_2)/N_1(v_1 - b_1)] + N_2 \ln[(V - N_1 b_1 - N_2 b_2)/N_2(v_2 - b_2)]$$

where N_1 and N_2 denote numbers of moles, V the volume of solution, v_1 and v_2 the molal volumes of the pure components and b_1 and b_2 the sum of the actual geometrical volumes of 6×10^{23} molecules. Serge Gratch, USA

1065. **I. Prigogine, "On the dynamics of gas mixtures with consideration of diffusion"** (in French), *Bull. Acad. Belg. Cl. Sci.*, 1948, vol. 34, no. 10, pp. 789–794.

The equation of transport of molecular properties is discussed in the form introduced by de Donder and Géhéniau. It is emphasized that the equation of flow for a gas mixture assumes a simple form if the mass velocity as introduced by Chapman and Cowling is used. This mass average of the velocities of the molecules is here called barycentric velocity. The opinion espressed by Verschaffelt that an eventual temperature-gradient appears linearly in the equations of flow is shown to be incorrect.

H. C. Brinkman, Holland

1066. **Otto Dinkelacker, "The moist adiabatic processes of closed systems and the derived adiabatics"** (in German), *Z. Met.*, Mar. 1948, vol. 2, pp. 65–71.

This paper is concerned with a purely thermodynamic analysis of a mixture of air, water vapor, and liquid water. Treating the mixture as homogeneous and static, and neglecting thermal conduction, radiation, etc., the author writes down the equation of energy balance. He thus obtains a differential equation for the adiabatic (isoenergetic) curves, which he integrates, either exactly or approximately, and discusses in five special cases: (1) neither water nor water vapor is present; (2) no liquid water is present and the water vapor remains constant; (3) the sum of the water and water vapor remains constant; (4) no liquid water is present,

but condensation begins; (5) condensation takes place under assumptions which the reviewer cannot understand.

C. Truesdell, USA

Heat Transfer; Diffusion

(See also Revs. 1065, 1078)

1067. Hidekichi Kataoka, "Linear conduction of heat in a compound rod (2nd report)" (in Japanese), *Trans. Soc. mech. Engrs. Japan*, 1948, vol. 14, no. 46, pp. 168–170.

In this paper the author solves the equation of linear heat conduction for a rod of finite length which is constructed by connecting two rods of different materials, for the case when a constant amount of heat is supplied at one end and radiation takes place at the other end.

Humio Tamaki, Japan

1068. Hidekichi Kataoka, "Linear conduction of heat in a compound rod (3rd report)" (in Japanese), *Trans. Soc. mech. Engrs. Japan*, 1948, vol. 14, no. 47, part 2, pp. 29–35.

This paper deals with the case of a semi-infinite rod, which is constructed of two rods of different materials, the one being finite and the other infinite in length. The equation of linear heat conduction is solved for the boundary condition that a constant amount of heat is supplied and radiation takes place at the end.

Humio Tamaki, Japan

1069. Masayosi Sawada, "Concerning problems of thermal conduction in bodies having thermal coefficients affected by position, time or temperature" (in Japanese), *Trans. Soc. mech. Engrs. Japan*, 1947, vol. 13, no. 43, pp. 79–83; 1948, vol. 14, no. 47, pp. 18–29.

In the first paper the author presents an analysis which supplements the method proposed by Masao Sawada [*J. Soc. mech. Engrs. Japan*, 1934, vol. 37, no. 201, p. 15; *Trans. Soc. mech. Engrs. Japan*, 1935, vol. 1, no. 1, p. 39] for solving the equation of three-dimensional heat conduction, in which both heat conductivity and heat capacity are expressed as products of functions, each containing only the temperature, position coordinates and time, respectively. Instead of the temperature, the coordinates and time, suitable integrals containing the function which represent the form of heat conductivity and heat capacity are used as the variables for solving the equation.

The second paper deals with the solution of the equation of heat conduction, in which both heat conductivity and heat capacity are linear functions of temperature. The author presents a new method of successive approximations for solving the problem of the cooling of a plate, circular cylinder or sphere, which is initially at a certain uniform temperature and is cooled by the radiation from the surface. As a numerical example the author calculates the cooling of a plate and a sphere of 0.8 per cent carbon steel. The variations of temperature with time at the center and at the surface are shown in diagrams.

Humio Tamaki, Japan

1070. Sugao Sugawara and Takashi Satō, "Experimental research on the problems of heat transfer in packed tubes" (in Japanese), *Trans. Soc. mech. Engrs. Japan*, 1947, vol. 13, no. 45, pp. 164–185.

Heat transfer in tubes filled with small balls is experimentally investigated for the purpose of studying the nature of heat transfer in the catalyzer layer in a catalytic chamber. For the case when hot air passes through the tube packed with steel or glass balls, or with actual catalyzer particles, the temperature distribution over the surface of the tube, heat conductivity of the packed layers, and heat-transfer coefficient at the inner surface of the tube are determined. The effects of the heat of reaction, which is present in the actual catalytic reaction, are simply neglected in the experiments reported here. Further experiments taking these effects into consideration are now in progress.

Humio Tamaki, Japan

Acoustics

(See also Revs. 982, 1011)

1071. Mario Taddei, "A method of ultrasonic exploration" (in Italian), *Ann. Ist. Univ. Nav.*, 1947, vol. 14-15, pp. 133–149.

The paper describes the measuring apparatus and some results obtained for the speed of sound in liquid solutions. The measuring apparatus consists of a vessel with an oscillating quartz crystal on one end and a reflecting surface on the other end. The quartz is oscillated at its fundamental frequency, 585 kc. The vessel has two glass windows and the wave length of the standing waves is measured visually by a cathetometer. An analysis of the optical refraction in a stratified medium is included.

Measurements on aqueous solutions of different nitrates were carried out, and the results show that the speed of sound varies linearly with concentration for small concentrations, but fails to do so when the concentration is close to saturation.

Unfortunately the author did not include a list of references to the papers whose authors he mentions.

Leslie S. G. Kovasznay, USA

Ballistics, Detonics (Explosions)

(See also Revs. 970, 1038)

1072. M. E. Dubois, "Research on waves issuing from a source of explosion" (in French), *Mémor. Artill. fr.*, 1947, vol. 21, no. 2, pp. 369–393.

Pressure-time curves of the shock waves in air produced by explosive charges have been measured by means of quartz piezoelectric gages. Possible sources of error in this method of instrumentation are carefully discussed. The measured pressure-time curves exhibit an abrupt rise to a peak value, followed by a decay, roughly exponential in character, to negative pressures. The negative phase of the profile is followed by a secondary pressure pulse whose amplitude is a small fraction of that of the primary shock wave. The secondary pressure pulse does not appear to have a negative phase. The experimental results that are presented are scattered and unsystematic. No use of the scaling law was made in their interpretation. A qualitative discussion is given of the effects of air blast waves on walls of finite and of infinite extent. In the former discussion, the effects of diffraction are not considered.

Stuart R. Brinkley, Jr., USA

1073. H. Muraour, G. Aunis, and J. Domart, "Determination of burning-constant of smokeless powders in a closed bomb" (in French), *Mémor. Artill. fr.*, 1948, vol. 22, no. 3, pp. 518–593.

Extremely detailed instructions, including a table of logarithms, are presented for routine computation of the pressure-time integral from a closed-vessel record, and for determination of b in the assumed law: rate of burning $= a + bP$. Experimental results are given for the effects of the hardness of the copper used, weight of black-powder igniter, noncentral copper, and errors of reading records.

J. Corner, England

1074. **Robert H. Cole, "Underwater explosions,"** Princeton Univ. Press, Princeton, 1948. Cloth, 9.2 × 6.2 in., 437 pp., 116 figs., $7.50.

The first chapter presents a qualitative description of the sequence of events following an underwater explosion, which serves to orient the reader and to provide an outline for the remainder of the book. There follows a review of the fundamental hydrodynamics pertinent to the study and a review of the theory of the detonation process within the explosive charge. The theory of the underwater shock wave is developed in detail, and compared with experiment.

The theories of Kirkwood and Bethe, Kirkwood and Brinkley, and Penney for the propagation of spherical shock waves are developed and compared. The treatment by Rice and Ginnell of the shock wave with cylindrical symmetry is described. The asymptotic behavior of shock waves at large distances from the initiating charge is discussed. In later chapters, experimental measurements of shock-wave properties are compared with the predictions of theory.

The oscillatory motion of the bubble of detonation products, the migration of the bubble due to its buoyancy, the effect on the bubble motion of the neighboring surfaces, and the pressure pulses generated by the bubble motion are considered at length. In the main, the discussion of bubble theory is based upon the incompressible approximation of hydrodynamics. The effects of compressibility on the bubble motion are briefly considered.

There are chapters on the measurement of transient pressures and the application of optical methods to the study of underwater explosion phenomena. A brief description is given of the effects of an nuderwater explosion on the surface of the water, and brief consideration is given to the effects of pressure waves on the displacement and deformation of simple structures. In each section, there are numerous references to the literature. A valuable feature of the book is the emphasis placed on the appropriate scaling laws in the theoretical discussion and in the interpretation of experiment. This volume makes accessible a large amount of information resulting from wartime research that has been difficult to obtain.

The author has performed with skill the difficult task of selection and condensation necessary to cover his subject in a volume of moderate size. Stuart R. Brinkley, USA

Soil Mechanics, Seepage

1075. **Donald M. Burmister, "The importance and practical use of relative density in soil mechanics,"** *Proc. Amer. Soc. Test. Mat.*, 1948, vol. 48, pp. 1249–1268.

Relative density is defined as a percentage lying between the limits of zero and 100 per cent, for soil in its loosest and densest states respectively. This concept is suggested as a common parameter, for use with both granular and clay-type soils, to help harmonize various data on bearing value, driving resistance of samplers, compressibility, angle of friction, permeability, and gradation. The effect of soil structure is recognized as complicating the relationships. C. Martin Duke, USA

Geophysics, Meteorology, Oceanography

(See also Revs. 1025, 1028, 1045, 1047, 1066)

1076. **R. P. Pierre Lejay, "The modern development of the science of gravity measurement (Développements modernes de la gravimétrie),"** Gauthier-Villars, Paris, 1947. Paper, 9.9 × 6.5 in., 243 pp., 75 figs.

An expository treatment. George P. Woollard, USA

1077. **Wolfgang Kaempfert, "Nomograms for the turbidity factor"** (in German), *Met. Rdsch.*, Jan.-Feb. 1948, vol. 1, pp. 215–218.

The turbidity factor T was introduced into meteorology by F. Linke in 1922, by means of the equation $I_m = I_0 \exp(-a_m T m)$, where I_m is the measured intensity of radiation, I_0 the solar constant, a_m the coefficient of extinction in a pure and dry atmosphere, and m the mass. The author gives seven nomograms involving the parameters necessary for quick calculation of the turbidity factor after the observation.

Horst Merbt, England

1078. **Jiro Sakagami, "On the difference between diffusion phenomena in the cases when the diffusion coefficient is a constant and when it is proportional to the height"** (in Japanese), *J. met. Soc. Japan*, July 1948, vol. 26, pp. 81–84.

Solving the equation of diffusion $\partial c/\partial z = \partial(\kappa \partial c/\partial z)/\partial z$ for the two cases of κ constant and proportional to the height, the author compares the solutions with his experimental data. The result obtained shows that for diffusion near the ground it is more reasonable to assume that κ is proportional to the height.

Sigekata Syōno, Japan

1079. **H. K. Barrows, "Floods, their hydrology and control,"** McGraw-Hill Book Co., New York, 1948. Cloth, 9.2 × 6.1 in., 432 pp., 109 figs., $6.50.

This book is a compilation of (1) notes and data on the meteorology and hydrology of floods and of (2) abstracts of pertinent facts and figures relative to flood control and other river works constructed in the United States. The theoretical considerations with which the book deals are covered in something less than 10 per cent of its pages. The theoretical treatment of meteorology and hydrology is therefore valuable primarily as a summary and through the references to original articles.

A brief history of all the notable floods in the United States is presented. Data on flood losses and the use of reservoirs for flood protection appear in numerous tables. The major and most valuable part of the book consists of the brief description of the major American river-control works with abstracts of data on size and costs and with tables which summarize this information for the purpose of comparison and calculation of average values.

The levees, walls, revetments, channel improvements, reservoirs, power plants and navigation works constructed by the United States Corps of Engineers, United States Bureau of Reclamation, the Miami Conservancy District, the TVA and other public agencies are covered for the following river basins: (1) Lower Mississippi River Basin, (2) Ohio, Missouri and Upper Mississippi River, (3) White, Red, Arkansas and Ouachita Rivers, (4) Tennessee Valley Authority, (5) Connecticut and Merrimac Rivers, (6) Willamette River, Bonneville, Los Angeles, (7) The Central Valley of California, (8) Colorado and the Columbia River Basins, and others. John C. Geyer, USA

1080. **K. E. Bullen, "Introduction to the theory of seismology,"** Cambridge University Press, London, 1947. Cloth, 8.7 × 5.5 in., 276 pp., 43 figs., $4.

The book is intended to be an introduction to seismological theory. It is an attempt to meet the needs of seismologists for a book which gives the essentials of the theory in a fairly compact form, and the needs of undergraduates who are interested in seismology as a branch of applied mathematics and physics.

The book opens with a comprehensive introduction to the theory of elasticity and vibrations of homogeneous, elastic, iso-

stropic bodies, using the summation convention. Consideration of nonisotropic materials, viscosity, plasticity and finite strain theory are discussed briefly.

The elementary theories of simple harmonic motion and damped and forced vibrations are given in some detail because they are fundamental to later chapters on vibrations and waves and theory of the seismograph. The chapter on vibrations and waves is especially well written and should be of interest to students of mathematical physics. The chapter on surface elastic waves is devoted particularly to Rayleigh and Love waves which are important in seismology. The theory of the transmission of bodily seismic waves in the interior of an earth model assumed to be spherical and completely symmetric about its center is discussed. This leads to the theory of seismic rays.

A clear presentation of the principle of the seismograph is given. The features of seismograms are explained and the construction of travel-time tables is discussed. An account of the organization of a typical seismological observatory should provide an interesting introduction for those not actively working in the field of seismology. Finally, a discussion of seismology and of the upper layers and the deep interior of the earth are followed by a discussion of earthquake occurrence.

R. L. Bisplinghoff, USA

Lubrication; Bearings; Wear

(See also Rev. 989)

1081. Yutaka Sugimoto, "Theory of film-lubricated bearings of finite lengths" (in Japanese), *Trans. Soc. mech. Engrs. Japan*, 1948, vol. 14, no. 46, pp. 115–122.

The author transforms the fundamental Reynolds equation of lubrication into the form

$$d^2v/d\theta^2 + \tfrac{1}{2}f(\theta) - k_n{}^2\tfrac{1}{2}V + g(\theta) = 0,$$

where v denotes the pressure, θ the bearing angle, k_n the radius and $f(\theta)$ and $g(\theta)$ functions of θ. He then expands v into a Fourier series in the form $v(\theta) = \Sigma_1^\infty A_s F_s(\theta)$ $A_s = {}_{\theta_1}\int^\pi v(\theta)F_s(\theta)d\theta$, and obtains an infinite set of simultaneous equations. Neglecting small factors, he gets the pressure distribution in the bearing by successive approximation. In this solution, the angle θ_1 at which the pressure begins to rise is involved in general form.

Norimune Soda, Japan

1082. S. A. McKee, J. F. Swindells, H. S. White, and Wayne Mountjoy, "Laboratory wear tests with automotive gear lubricants," *J. Res. nat. Bur. Stands.*, Feb. 1949, vol. 42, pp. 125–130.

The SAE lubricant test machine has been modified to provide better temperature control of the upper test cup and has been operated for prolonged periods at constant load. This novel procedure has been devised to obtain information on rate of wear under high loads and low speeds, as contrasted with the normal use of the machine in which load-carrying capacity is assessed under conditions of high-speed and "shock" loading. Test conditions were as follows: operating temperature 225 F; loads 90, 135, 180 and 225 lb.; speed 500 rpm, with a 2.4 to 1 ratio of rubbing to rolling at the contacting surfaces; the duration of most tests was 25 hr. Wear was determined by weighing at intervals of 4, 11, 18 and 25 hr.

Curves showing rate of wear against time for various loads are given for a straight mineral oil and for 11 representative samples of commercial lubricants. Generally wear was rapid for the first 2 hr, after which it assumed a smaller constant rate. Surface finish usually improved during the initial running-in period. In other instances, particularly at high-load, wear continued at a high rate; in such cases the surfaces became rougher as the test proceeded. It is concluded that lubricants containing the more chemically active additives tend to show the greater wear.

F. T. Barwell, England

1083. John W. Pennington, "Piston ring and cylinder wear in Diesel engines," *Soc. auto. Engrs. J.*, Feb. 1949, vol. 57, pp. 39–44.

The author reviews the principal factors which he thinks are important in connection with wear, such as direct mechanical action, scuffing, surface disintegration, abrasion and corrosion. He gives some experimental data showing the effect of dust, jacket temperature, high-sulphur fuel and chrome plate on the amount of wear and the wear profile of cylinders and rings, as well as a few scuffing tests showing the effect of sulphurized lubricant and the surface finish of the ring. The results generally confirm other reported experiences with these factors. Wear of a cylinder was determined by measuring the wear step, using a dial gage; a neat instrument for holding and traversing the dial gage is described.

John T. Burwell, Jr., USA

Marine Engineering Problems

1084. Werner Hinterthan, "Model statistics as compiled by the Hamburg model basin," *David Taylor Model Basin Rep.*, no. 674, Dec. 1948, 7 pp.

This report presents information on the compilation of statistical data obtained from a large number of ship model tests. Plots are given of various resistance coefficients as functions of Froude's number. Curves of section areas and section-area radii are also given.

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